2015 ANNUAL SITE-WIDE GROUNDWATER, SURFACE WATER, AND SEDIMENT MONITORING REPORT FOR OU-7, OU-10, AND NTCRA BASINS

AVTEX FIBERS SUPERFUND SITE
FRONT ROYAL, VIRGINIA

Prepared for:

FMC Corporation
2929 Walnut Street
Philadelphia, PA 19104

Prepared by:

PARSONS
404 Kendrick Lane
Front Royal, Virginia 22630

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Parsons PN 449965

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TABLE OF CONTENTS

TABLE OF CONTENTS .... i~~i~~

ACRONYMS .... vii~~vii~~

EXECUTIVE SUMMARY .... i~~i~~

1.0 Introduction .... 1~~1~~

- **1.1 Background** .... 1~~1~~
- **1.2 Monitoring Objectives** 2
- **1.3 Well Inspections** .... 3~~3~~
- **1.4 Sample Collection Procedures** .... 4~~4~~
  - 1.4.1 Sample Identification .... 4~~4~~
  - 1.4.2 Well Purging .... 4~~4~~
  - 1.4.3 Measurement of Field Parameters .... 4~~4~~
  - 1.4.4 Groundwater Sample Collection .... 4~~4~~
  - 1.4.5 Surface Water and Sediment Sample Collection .... 5~~5~~
  - 1.4.6 Aquatic Biota Sample Collection .... 5~~5~~
- **1.5 Quality Assurance** .... 5~~5~~
- **1.6 Report Organization** .... 6~~6~~

2.0 OU-7 Capture Zone Groundwater Monitoring .... 7~~7~~

- **2.1 Monitoring Well Network** .... 7~~7~~
- **2.2 Water Level Measurements** .... 8~~8~~
- **2.3 Capture Zone Analysis** .... 8~~8~~
- **2.4 Sample Analysis** .... 11~~11~~
- **2.5 Quality Assurance** .... 12~~12~~
- **2.6 Results** .... 13~~13~~
  - 2.6.1 VOCs .... 14~~14~~
  - 2.6.2 SVOCs .... 15~~15~~
  - 2.6.3 Inorganic Constituents .... 15~~15~~
- **2.7 Plume Delineation** .... 19~~19~~
- **2.8 Conclusions** .... 20~~20~~

3.0 OU-7 Post-Closure Groundwater Monitoring .... 23~~23~~

- **3.1 Monitoring Well Network** .... 23~~23~~
- **3.2 Water Level Measurements** .... 23~~23~~
- **3.3 Sample Analysis** .... 24~~24~~

3.4 Quality Assurance .... 24~~24~~
3.5 Results .... 25~~25~~
3.5.1 Upgradient Overburden Wells .... 25~~25~~
3.5.2 Downgradient Overburden Wells .... 25~~25~~
3.5.3 Upgradient Shallow Bedrock Wells .... 27~~27~~
3.5.4 Downgradient Shallow Bedrock Wells .... 28~~28~~
3.6 Control Charts .... 29~~29~~
3.7 Conclusions .... 31~~31~~
4.0 OU-10 Post-Closure Groundwater Monitoring .... 33~~33~~
4.1 Monitoring Well Network .... 33~~33~~
4.2 Water Level Measurements .... 34~~34~~
4.3 Sample Analysis .... 34~~34~~
4.4 Quality Assurance .... 35~~35~~
4.5 Results .... 36~~36~~
4.5.1 Viscose Basins 1-8 .... 36~~36~~
4.5.2 New Landfill .... 41~~41~~
4.6 Conclusions .... 42~~42~~
4.6.1 Viscose Basins 1-8 Overburden Groundwater .... 42~~42~~
4.6.2 Viscose Basins 1-8 Shallow Bedrock Groundwater .... 42~~42~~
4.6.3 New Landfill Overburden Groundwater .... 43~~43~~
4.6.4 New Landfill Shallow Bedrock Groundwater .... 43~~43~~
5.0 NTCRA Basin Post-Closure Groundwater Monitoring .... 45~~45~~
5.1 Monitoring Well Network .... 45~~45~~
5.1.1 Fly Ash Basin Monitoring Well Network .... 45~~45~~
5.1.1 Sulfate Basin Monitoring Well Network .... 45~~45~~
5.1.1 Fly Ash Basin Cover System Drains .... 46~~46~~
5.1.2 Sulfate Basin Cover System Drains .... 46~~46~~
5.2 Water Level Measurements .... 46~~46~~
5.3 Sample Analysis .... 47~~47~~
5.4 Quality Assurance .... 47~~47~~
5.5 Results .... 49~~49~~
5.5.1 Fly Ash Management Unit .... 49~~49~~
5.5.2 Sulfate Basin Management Unit .... 50~~50~~
5.5.3 Fly Ash Basin Cover System Drain Sumps .... 51~~51~~
5.5.4 Sulfate Basin Cover System Drain Sumps .... 52~~52~~

5.6 Conclusions .... **53~~53~~**
5.6.1 Fly Ash Management Unit .... 53~~53~~
5.6.2 Sulfate Basin Management Unit .... 53~~53~~
5.6.3 Fly Ash Basin Cover System Drain Sumps .... 53~~53~~
5.6.4 Sulfate Basin Cover System Drain Sumps .... 53~~53~~
6.0 OU-7 Surface Water and Sediment Monitoring .... **55~~55~~**
6.1 Sample Collection .... **55~~55~~**
6.1.1 Sample Locations .... 55~~55~~
6.1.2 Equipment Decontamination .... 56~~56~~
6.1.3 Measurement of Field Parameters .... 56~~56~~
6.1.4 River Water Sample Collection Procedures .... 56~~56~~
6.1.5 River Sediment Sample Collection Procedures .... 56~~56~~
6.2 Sample Analysis .... **57~~57~~**
6.3 Quality Assurance .... **58~~58~~**
6.4 Results .... **59~~59~~**
6.4.1 River Flow .... 59~~59~~
6.4.2 River Sediment .... 60~~60~~
6.4.3 River Water .... 61~~61~~
6.5 Conclusions .... **61~~61~~**
6.5.1 River Sediment .... 62~~6261~~
6.5.2 River Water .... 62~~62~~
7.0 OU-7 Aquatic Biota Sampling .... **63~~63~~**
7.1 Sample Locations .... **63~~63~~**
7.2 Sample Collection Procedures .... **63~~63~~**
7.2.1 Fish .... 64~~64~~
7.2.2 Benthic Macroinvertebrates .... 65~~65~~
7.3 Sample Analysis .... **65~~65~~**
7.4 Quality Assurance .... **65~~65~~**
7.5 Results .... **66~~66~~**
7.5.1 Fish .... 66~~66~~
7.5.2 Benthic Macroinvertebrates (Fingernail Clams) .... 68~~68~~
7.5.3 Sediment .... 68~~68~~
7.6 Conclusions .... **68~~68~~**
8.0 References .... **71~~71~~**

FIGURES

Figure 1	Site Location Map
Figure 2	OU-7 Capture Zone Monitoring Well Network
Figure 3A	OU-7 Overburden Groundwater Contour Map (March 18, 2015)
Figure 3B	OU-7 Overburden Groundwater Contour Map (July 7, 2015)
Figure 3C	OU-7 Overburden Groundwater Contour Map (Sep 15, 2015)
Figure 3D	OU-7 Overburden Groundwater Contour Map (Dec 8, 2015)
Figure 3E	OU-7 Overburden Groundwater Drawdown Map (Sep 15, 2015)
Figure 4A	OU-7 Shallow Bedrock Groundwater Contour Map (March 18, 2015)
Figure 4B	OU-7 Shallow Bedrock Groundwater Contour Map (July 7, 2015)
Figure 4C	OU-7 Shallow Bedrock Groundwater Contour Map (Sep 15, 2015)
Figure 4D	OU-7 Shallow Bedrock Groundwater Contour Map (Dec 8, 2015)
Figure 4E	OU-7 Shallow Bedrock Groundwater Drawdown Map (Sep 15, 2015)
Figure 5A	OU-7 Intermediate Bedrock Groundwater Contour Map (March 18, 2015)
Figure 5B	OU-7 Intermediate Bedrock Groundwater Contour Map (July 7, 2015)
Figure 5C	OU-7 Intermediate Bedrock Groundwater Contour Map (Sep 15, 2015)
Figure 5D	OU-7 Intermediate Bedrock Groundwater Contour Map (Dec 8, 2015)
Figure 5E	OU-7 Intermediate Bedrock Groundwater Drawdown Map (Sep 15, 2015)
Figure 6A	OU-7 Deep Bedrock Groundwater Contour Map (March 18, 2015)
Figure 6B	OU-7 Deep Bedrock Groundwater Contour Map (July 7, 2015)
Figure 6C	OU-7 Deep Bedrock Groundwater Contour Map (Sep 15, 2015)
Figure 6D	OU-7 Deep Bedrock Groundwater Contour Map (Dec 8, 2015)
Figure 6E	OU-7 Deep Bedrock Groundwater Drawdown Map (Sep 15, 2015)
Figure 7	Hydrogeologic Cross-Section A-A’ September 2015
Figure 8	Hydrogeologic Cross-Section B-B’ September 2015
Figure 9	Hydrogeologic Cross-Section C-C’ September 2015
Figure 10	Hydrogeologic Cross-Section D-D’ September 2015
Figure 11	OU-7 Overburden Groundwater Isoconcentration Contour Map (July 2015)
Figure 12	OU-7 Shallow Bedrock Groundwater Isoconcentration Contour Map (July 2015)
Figure 13	OU-7 Intermediate Bedrock Groundwater Isoconcentration Contour Map (July 2015)
Figure 14	OU-7 Deep Bedrock Groundwater Isoconcentration Contour Map (July 2015)
Figure 15	OU-7 VSWMR Monitoring Well Network

Figure 16 OU-10 Viscose Basins 1-8 and New Landfill Overburden Groundwater Contour Map (July 2015)

Figure 17 OU-10 Viscose Basins 1-8 and New Landfill Shallow Bedrock Groundwater Contour Map (July 2015)

Figure 18 NTCRA Basins Overburden Groundwater Contour Map (July 2015)

Figure 19 NTCRA Basins Shallow Bedrock Groundwater Contour Map (July 2015)

Figure 20 River Water and Sediment Sample Locations

Figure 21 Aquatic Biota Sample Location Map

TABLES

Table 1 Monitoring Well Construction Details for the OU-7 Monitoring Network

Table 2 Monitoring Well Construction Details for the OU-10 Monitoring Network

Table 3 Monitoring Well Construction Details for the NTCRA Basins Monitoring Network

Table 4 Monitoring Well Purging and Sampling Details for the OU-7 Monitoring Network

Table 5 Monitoring Well Purging and Sampling Details for the OU-10 Monitoring Network

Table 6 Monitoring Well Purging and Sampling Details for the NTCRA Basins

Table 7 OU-7 Groundwater Elevation Measurements

Table 8 Operational History for Extraction Wells

Table 9 OU-7 Monitoring Network Sampling Results

Table 10 OU-7 VSWMR Monitoring Network Sampling Results

Table 11 OU-10 Groundwater Elevation Measurements

Table 12 OU-10 Viscose Basins 1-8 Groundwater Monitoring Network Sampling Results

Table 13 OU-10 New Landfill Groundwater Monitoring Network Sampling Results

Table 14 OU-10 Comparison of Results to Baseline Conditions

Table 15 Sulfate Basins and Fly Ash Management Units Groundwater Elevation Measurements

Table 16 NTCRA Basins Groundwater Monitoring Results

Table 17 NTCRA Basins Sump Monitoring Results

Table 18 Fly Ash Basins Comparisons of Results to Baseline Conditions

Table 19 Sulfate Basins Comparisons of Results to Baseline Conditions

Table 20 OU-7 River Sediment Sample Results

Table 21 OU-7 River Water Sample Results

Table 22 OU-7 River Aquatic Biota Sample Information

Table 23 OU-7 River Aquatic Biota Fish Sample Results
Table 24 OU-7 River Aquatic Biota Macroinvertebrate Sample Results
Table 25 OU-7 River Aquatic Biota Sediment Sample Results

APPENDICES

Appendix A Sampling Logs
Appendix B Data Validation Reports
Appendix C Laboratory Reports
Appendix D Historical Groundwater Results
Appendix E VSWMR Control Charts
Appendix F OU-10 Control Charts
Appendix G NTCRA Basin Control Charts
Appendix H Historical Surface Water and Sediment Results
Appendix I Historical Aquatic Biota Sample Results

ACRONYMS

Acronym	Definition / Description
Avtex	Avtex Fibers, Inc.
CCV	Continuing calibration verification
cfs	Cubic feet per second
COPC	Compounds of potential concern
DMC	Deuterate monitoring compounds
DQO	Data quality objective
ECCI	Environmental Chemistry Consultants, Inc.
ERM	Environmental Resource Management, Inc.
FAB	Fly Ash Basins
FLUTe	Flexible Liner Underground Technologies
FMC	FMC Corporation
FS	Feasibility study
GWMP	Groundwater Monitoring Plan
IS	Internal Standards
Lancaster	Eurofins Lancaster Laboratories Environmental, LLC
MDL	Method detection limit
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
mg/kg	Milligram(s) per kilogram
mg/L	Milligram(s) per liter
mS/Cm	Milli-Siemens per centimeter
MS/MSD	Matrix spike / matrix spike duplicate
NPL	National Priorities List
NTCRA	Non-Time Critical Removal Action
O&M	Operation and maintenance
OU	Operable Unit
QA/QC	Quality assurance / quality control
QAPP	Quality Assurance Project Plan
Pace	Pace Analytical Services, Inc.
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethylene
RI	Remedial investigation
RL	Reporting limit
RSL	Regional Screening Level
SB	Sulfate Basins
SDG	Sample data group
Site	Avtex Fibers Superfund Site, Front Royal, Virginia

Acronym	Definition / Description
SVOC	Semivolatile organic compound
SW&SMP	Surface Water and Sediment Monitoring Plan
TCL	Target compound list
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VAC	Virginia Administrative Code
VADEQ	Virginia Department of Environmental Quality
VB	Viscose Basins
VOC	Volatile organic compound
VSWMR	Virginia Solid Waste Management Regulation

EXECUTIVE SUMMARY

Parsons has prepared this annual monitoring report on behalf of FMC Corporation (FMC) to present the results of the 2015 site-wide annual groundwater, surface water, and sediment sampling event at the Avtex Fibers Superfund Site in Front Royal, Virginia (Site). Groundwater monitoring was conducted in accordance with the Site-Wide Groundwater Monitoring Plan (GWMP) Revision 1 (Environmental Resource Management [ERM] 2015), which was approved by the United States Environmental Protection Agency (USEPA) on February 27, 2015. The following annual monitoring elements and activities are included in this report:

- Capture zone analysis for Operable Unit 7 (OU-7)
- Groundwater quality monitoring for the closed Viscose Basin (VB) 9-11 units in accordance with Virginia Solid Waste Management Regulations (VSWMRs)
- Post-closure monitoring activities for VB 1-8 and the New Landfill and Non-Time-Critical Removal Action (NTCRA) Basins in accordance with VSWMRs
- Results of the 2015 surface water and sediment sampling conducted as part of implementing the USEPA-approved Surface Water and Sediment Monitoring Plan (SW&SMP) for OU-7 (ERM 2014)
- Results of the 2015 triennial aquatic biota sampling required by the SW&SMP

Key findings associated with the 2015 groundwater quality data for OU-7 are summarized below:

- Concentrations of carbon disulfide have shown a noticeable decrease since groundwater extraction began.
- Carbon disulfide concentrations at all of the overburden~~shallow bedrock~~ wells are below the OU-7 groundwater cleanup standard and only one shallow bedrock well exceeds the cleanup standard, indicating that the plume has quickly attenuated in the overburden and shallow bedrock zones.
- The leading edge of the carbon disulfide plume in the intermediate and deep bedrock has migrated beneath the Shenandoah River. However, the plume has narrowed considerably and shortened at both the upgradient and downgradient ends since pumping began.
- Concentrations of inorganic constituents are stable or decreasing.
- For the third consecutive year, there were no exceedances of the OU-7 groundwater cleanup standards in wells 501A, B and C. Similarly, there were no exceedances of the OU-7 groundwater cleanup standards in wells 606A and 606B.
- The results indicate that several constituents are present in groundwater above their baseline concentrations at wells MW-09 (methylphenol, phenol, arsenic, chromium, cobalt, nickel, and vanadium) and WP-10 (cobalt). However, these constituents were not significantly above their baseline concentrations. Additional data are required to establish a statistically significant pattern showing an increase in groundwater concentrations.
- The capture zone analysis indicates that:
    - There is a well-developed cone of depression in the shallow and intermediate bedrock between wells TW-01 and TW-02 and extending across the river.

- The deep bedrock drawdown also indicates an elongated cone of depression that extends from TW-02 through TW-01 and across the river to TW-03. However, drawdown values are more variable in this zone, possibly indicating less well-connected fractures.
- The effects of pumping from across the river are evident, and the capture zone created by pumping at TW-03 has now extended to the southeast of TW-03.

Key findings associated with the 2015 OU-10 Post Closure Groundwater Sampling are summarized below:

- Overburden groundwater:
    - With a few exceptions, volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) are not present in the overburden groundwater downgradient of Viscose Basins (VBs) 1-8.
    - Four VOCs (acetone, methyl ethyl ketone, 2-hexanone, and xylenes) were detected at a concentration exceeding the baseline range at well GPW-14 (this is the first time these constituents have been detected above the baseline range at this location). Since these constituents have not appeared in upgradient wells or have only been detected at relatively low concentrations, VBs 1-8 may be contributing trace levels of VOCs to groundwater in the overburden aquifer. Future sampling events will provide the data required to determine if the unit is causing an increase in these constituent concentrations.
    - New Landfill: the two wells that are representative of upgradient overburden groundwater quality at the New Landfill have been sampled, but all downgradient overburden monitoring wells have been dry during the monitoring events. Based on the dry conditions at the downgradient monitoring wells, it appears that minimal overburden groundwater is present beneath and downgradient of the New Landfill.
- Shallow bedrock groundwater:
    - With a few exceptions at well 119, VOCs and SVOCs are not present in the shallow bedrock groundwater downgradient of VB 1-8. The only constituents detected in downgradient shallow bedrock groundwater above their baseline concentrations were xylenes and antimony at well 119. While the xylenes concentration was slightly above the baseline value, the upgradient concentrations also appear to be increasing slightly. This is the first exceedance of the baseline for either of these constituents. Continued monitoring is required to determine if there is an increasing trend at this location.
    - New Landfill wells:
        - Carbon disulfide (well 133) and vinyl chloride (well MW-07) were the only VOCs detected in the shallow bedrock monitoring wells downgradient of the New Landfill during the 2015 sampling event. Both detections exceeded their respective baseline ranges. Carbon disulfide has been intermittently detected at well 133, and vinyl chloride has been present in well MW-07 since 2013. There are insufficient data to determine if the concentrations of these constituents are increasing or stable. Continued monitoring is required to determine if there is an increasing trend at this location.

- No SVOCs were detected in the shallow bedrock monitoring wells downgradient of the New Landfill during the 2015 sampling event. Therefore, the New Landfill does not appear to be contributing significant VOCs or SVOCs to groundwater in the shallow bedrock.
- Concentrations of arsenic, beryllium, and nickel are elevated in shallow bedrock wells downgradient of the New Landfill compared to the upgradient shallow bedrock wells, suggesting that these constituents may be derived from the New Landfill. However, with the exception of arsenic at well 133, the detected concentrations for these metals were below or within the range of baseline values in their respective wells. Additional monitoring data are required to determine if an increasing trend for arsenic is present at this location.

Key findings associated with the 2015 NTCRA Basin Post-Closure Groundwater Sampling are summarized below:

- Fly Ash Basins (FABs) overburden groundwater:
  - Metals monitoring in the overburden wells indicates a potential increasing trend of arsenic concentrations in well 014R downgradient of FAB 3 relative to the concentration in the upgradient well. However, the concentrations of arsenic have remained relatively stable since 2008. The potential increasing trend for arsenic at well 014R will be tracked in subsequent monitoring events.
  - Sodium and sulfate concentrations at well 014R have notably increased since the inception of the monitoring program in 2001.
- FABs shallow bedrock groundwater:
  - Metals monitoring in the shallow bedrock wells both upgradient and downgradient of the FAB units did not indicate increasing trends in metal concentrations except nickel in well 114. A potential increasing trend in nickel concentrations have been observed at this well, although the concentrations remain an order of magnitude below the Regional Screening Level.
  - Sulfate concentrations in downgradient wells 112 and 114 were elevated relative to the upgradient wells and concentrations measured during baseline data collection.
- Sulfate Basins (SBs) overburden groundwater:
  - Metals monitoring in the overburden wells both upgradient and downgradient of the SBs did not indicate any increasing trends in metal concentrations. The major ion concentrations are also relatively stable.
- SBs shallow bedrock groundwater:
  - Metals monitoring in the shallow bedrock wells both upgradient and downgradient of the SBs did not indicate any increasing trends in metal concentrations.
- Sumps:
  - The water quality data collected from the sumps indicate that arsenic, nickel, zinc, and sulfate were present during the 2015 sampling event at concentrations

exceeding Virginia's surface water quality standards (9 VAC[1] 25-260-140). With the exception of arsenic at sump FAB-1-2, the concentrations of these constituents have decreased or remained stable over time. Additional data are required to determine if the increase at FAB-1-2 is an anomaly or represents a trend.

- The 2015 event represents the 10th sampling event for sumps SB 4-1 and SB 4-2, the sixth sampling event for SB 3-1, and the fourth sampling event for sumps SB 1-1, SB 1-2, SB 1-3, and SB 1-4. The water quality data indicate that arsenic, nickel, and sulfate were present at concentrations exceeding Virginia's surface water quality standards (9 VAC 25-260-140). The concentrations of compounds of potential concern in these sumps has decreased or remained stable over the monitoring period.

Key findings associated with the 2015 surface water and sediment sampling for OU-7 are summarized below:

- Sediment:
  - Consistent with past sampling events, carbon disulfide was detected in sediment samples near the OU-7 plume above the sediment criteria. The concentrations detected in sediment were similar to previous levels.
  - 4-methylphenol was detected above the sediment criteria at upstream location SED-08. No other VOCs or SVOCs were detected at concentrations above the sediment criteria.
  - With the exception of iron, manganese, and mercury, all metals were reported as non-detect or at concentrations below the freshwater sediment screening benchmarks. The concentrations of metals detected in sediments in 2015 are consistent with results reported from 2013 and 2014.
  - The highest SVOC and metals concentrations in sediment were reported in the upstream sample SED-08.
  - Consistent with historical results, total cyanide was not detected in any of the samples.
- Surface Water:
  - No VOCs or SVOCs were detected in river surface water samples.
  - Concentrations of metals in river surface water samples were reported as non-detect or at concentrations below the surface water criteria at all sampling locations. This is consistent with historical results.

Key findings associated with the 2015 aquatic biota and sediment sampling for OU-7 are summarized below:

- Significant decreases in polychlorinated biphenyl (PCB) concentrations has been observed in the smallmouth bass and redbreast sunfish samples since 2013. Comparing the results for the comely shiner to the previous bluntnose minnow results indicates similar concentrations between 2013 and 2015.

[1] VAC – Virginia Administrative Code

- Spatially, upstream location BMI-6 had the fewest exceedances of the screening criterion for PCBs while downstream location BMI-02 had the most exceedances.
- PCBs were detected in only one clam tissue sample (BMI-2). The detected PCB concentration at BMI-2 (0.0159 J milligrams per kilogram) is less than the method detection limit obtained in 2013. This represents a significant decrease in concentrations since the 1999 sampling event conducted by USEPA. No Virginia Department of Environmental Quality screening value is provided for shellfish not subject to human consumption.
- PCBs were not detected in the sediment samples collected from any of the six aquatic biota sample locations at concentrations above the method detection limit.

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1.0 INTRODUCTION

Parsons has prepared this annual monitoring report on behalf of FMC Corporation (FMC) to present the results of the 2015 site-wide annual groundwater sampling event at the Avtex Fibers Superfund Site in Front Royal, Virginia (Site). Groundwater monitoring was conducted in accordance with the Site-Wide Groundwater Monitoring Plan (GWMP) Revision 1 (Environmental Resource Management [ERM] 2015), which was approved by the United States Environmental Protection Agency (USEPA) on February 27, 2015.

As part of the 100% design submittal, the Non-Time Critical Removal Action (NTCRA) Basins and Operable Unit 10 (OU-10, consisting of Viscose Basins [VB] 1-8 and the New Landfill) monitoring programs were combined with the requirements set forth in the GWMP for OU-7 to create a single, comprehensive groundwater monitoring program. The 2015 annual event represents the second annual event since merging the monitoring programs.

The following annual monitoring elements and activities are included in this report:

- Capture zone analysis for OU-7
- Groundwater quality monitoring for the closed VB 9-11 units in accordance with Virginia Solid Waste Management Regulations (VSWMRs)
- Post-closure monitoring activities for VB 1-8 and the New Landfill and NTCRA Basins in accordance with VSWMRs
- Results of the 2015 surface water and sediment sampling conducted as part of implementing the USEPA-approved Surface Water and Sediment Monitoring Plan (SW&SMP) for OU-7 (ERM 2014)
- Results of the 2015 triennial aquatic biota sampling required by the SW&SMP

1.1 Background

FMC has completed removal and remedial activities at the Site. The removal action, remedial design, and remedial action activities were performed pursuant to the 1999 Consent Decree between the United States of America and FMC Corporation (effective October 21, 1999). The Site has now transitioned into the operations and maintenance (O&M) phase of the remedy.

The approximately 440-acre Avtex Fibers Superfund Site is a former rayon manufacturing facility located in Front Royal, Virginia. The Norfolk Southern railroad runs through the middle of the Site, separating the former production facilities on the eastern side of the railroad tracks from the disposal units located on the western side of the railroad tracks. Residential areas are located to the east, south and north of the property boundaries. The South Fork Shenandoah River is located along the western portion of the property. The Site location is shown on Figure 1.

Operations at the Site began in 1940, when American Viscose opened a rayon production plant. In 1963, American Viscose sold the plant and property to FMC. FMC sold the plant and property to Avtex Fibers, Inc. (Avtex) in 1976. The State of Virginia ordered Avtex to abruptly shut the plant down in November 1989. Avtex filed for bankruptcy shortly thereafter (1990).

Plant operations generated three major waste types: a zinc sulfate sludge, fly ash, and viscose waste (a high pH cellulose material containing carbon disulfide). Most of the wastes were disposed in a series of basins located on the western portion of the property. A significant groundwater plume resulted from chemical discharge from several of the viscose waste basins. Plant operations resulted in chemical impacts to the former manufacturing buildings and associated sewer system. Chemical releases from the plant area also resulted in soil contamination.

When groundwater contamination was discovered in residential wells, the Site was proposed for the National Priorities List (NPL) on October 15, 1984 (49 FR[2] 40320), and listed on the NPL on June 10, 1986 (51 -FR 21054). After Avtex declared bankruptcy, USEPA initiated emergency removal actions to mitigate releases from reactive and dangerous materials left in tanks, piping, and buildings. To facilitate management of the cleanup, the remediation activities were divided into 10 OUs and three removal actions. USEPA conducted emergency removal actions and remedial actions for OU2, OU3, OU4, OU5, and OU8 from 1989 until1999. In 1999, USEPA entered into a Comprehensive Consent Decree with FMC to implement the remaining required remedial activities.

Approximately 240 acres of the Site (western side of tracks) has been designated as a conservancy area. The former plant area comprises approximately 160 acres. A portion of the plant area, a 5-acre former parking lot, was sold to the town of Front Royal with plans to construct a police station. The Front Royal Economic Development Authority now owns the former plant area and is working to redevelop the area into a commercial/light industrial area.

On August 29, 2014, USEPA issued a document titled “Superfund Preliminary Close-out Report” that documented construction completion of the Site. The completion of construction at the Site marks the transition of the Site into the O&M phase.

1.2 Monitoring Objectives

The objectives for each of the monitoring activities summarized in this report are outlined below:

OU-7 Groundwater Monitoring

The OU-7 groundwater monitoring program objectives are twofold:

1. Monitor groundwater elevations and quality to evaluate remedy performance and support plume capture zone analyses; and
2. Monitor groundwater quality for the closed VB 9-11 units in accordance with the VSWMRs.

OU-7 Surface Water and Sediment

The objective for the OU-7 river and sediment monitoring is to collect surface water quality and sediment data to determine whether there are decreasing trends in the constituent concentrations found in surface water and sediments in the area where the groundwater contamination plume from VB 9-11 is entering the Shenandoah River.

[2] FR – Federal Register

OU-7 Aquatic Biota Sampling

Aquatic biota sampling is conducted to determine whether there are decreasing trends in the concentration of polychlorinated biphenyls (PCBs) found in the aquatic biota (i.e., fish and macroinvertebrates) that reside adjacent to the Site. In addition to the aquatic biota sampling, USEPA also requested that sediment samples be analyzed for PCBs, total organic carbon (TOC) and grain size to provide data necessary to establish the appropriate bioaccumulation factors.

OU-10 and NTCRA-Basins Groundwater Monitoring

The objective for the groundwater monitoring program for the closed OU-10 and NTCRA-Basin units is to determine whether groundwater quality becomes further degraded from the viscose and other waste within the units and, if so, whether there is an unacceptable risk posed by the change in water quality conditions.

1.3 Well Inspections

Section 2.4 of the OU-7 GWMP required inspection of all wells in the proposed monitoring well network to determine their integrity and accessibility. In addition, occasional depth to bottom measurements at each well are required to verify the constructed depth and measure sediment build up in the wells. The depth to bottom of most of the wells was recorded in 2014; however, some of the wells could not be measured due to measuring equipment issues. Additional measurements were therefore collected in 2015.

In June 2015, all the wells were found to be in working condition and accessible. The well construction details and 2015 depth to bottom readings for the OU-7, OU-10, and NTCRA Basin monitoring wells are shown on Tables 1 through 3, respectively. Depth to bottom readings could not be obtained at several of the wells. The FLUTe[3] liners installed in wells 603 and 604 prevent measurements of depth to bottom in those wells. Wells TMW-01, TMW-02, and TMW-03 have been converted to extraction wells. Depth to bottom measurements at wells 118, 119, 130R, GPW-16R, GPW-17, GPW-18, GPW-21, and MW-07 were inadvertently missed in 2015 and will be measured in 2016.

Significant sediment deposition (defined as 4 feet or more in a well) was observed at wells 091, 134, 305, GM-09, PW-0, PW-01, and PW-04. Four of these wells (091, 134, PW-01, and PW-04) are used for water level readings only and are not sampled. The table below summarizes the deposition in these wells.

Well	Deposition (Feet)	Screen Length (Feet)
091*	23.41	NA
134*	6	46
305	4.65	20
GM-09	33.8	99
PW-0	39	123
PW-01*	102.4	99
PW-04*	7	115

*Denotes wells that are only monitored for water level.

[3] Flexible Liner Underground Technologies

The amount of deposition noted at well PW-01 may indicate that the screen has collapsed. The depth to bottom reading for this well will be remeasured to confirm this finding.

1.4 Sample Collection Procedures

1.4.1 Sample Identification

Each sample was assigned a unique sample tracking number using the basic format described in Section 6.1 of the OU-7 GWMP. The sample identification numbers are coded on the format: Event-Location-Type. Each of these codes is defined below

- The Event code is always made up of the four-character Date Code + a two-character Event Code. For example, the event code for the annual monitoring event for 2015 is 2015AN.
- The Location Code is the unique well/sump identification number assigned to each location (e.g., PW-01).
- The optional Type code is used to describe special samples, as follows:
  - D (duplicate)
  - Z1, Z2, Z3, or Z4: depth code for FLUTe wells (representing zone 1, 2, 3, or 4)
  - MS/MSD (Matrix spike/matrix spike duplicate)
  - SUMP for Sumps

1.4.2 Well Purging

The wells were purged in accordance with the well purging and sampling procedures and any applicable alternative procedures outlined in Section 3.4.3 of the OU-7 GWMP (ERM 2015). Groundwater, surface water, and sediment purging and sampling began on July 7 and was completed on August 6, 2015. The purging method for each well is summarized in Tables 4 through 6 for the OU-7, OU-10, and NTCRA Basin monitoring well networks, respectively.

1.4.3 Measurement of Field Parameters

Field measurements for pH, conductivity, redox potential, dissolved oxygen, turbidity, and temperature were collected from groundwater wells in accordance with the procedures described in Sections 3.4.3 and 3.4.4 of the OU-7 GWMP. Field parameters were measured by directing the pump outflow through a flow-through cell in accordance with the methods for assembly and calibration provided in Attachment C of the OU-7 GWMP.

1.4.4 Groundwater Sample Collection

Groundwater samples were collected in accordance with the procedures described in Section 3.4.3 of the OU-7 GWMP. Samples collected for dissolved metals were field filtered through a 0.45-micron in-line filter. The filtrate was placed directly into the sample container with the appropriate preservatives. The time of collection and any observable characteristics of the sample were recorded in the field notebook or on the sample log. The sampling method for each well is summarized on Tables 4 through 6 for the OU-7, OU-10, and NTCRA Basin monitoring well networks, respectively. Sample logs are included in Appendix A.

1.4.5 Surface Water and Sediment Sample Collection

Surface water and sediment samples were collected in accordance with the procedures described in Section 2.3 of the SW&SMP. The samples were collected beginning with the most downstream sample and working progressively upstream. At each location, the surface water sample was collected before the sediment sample to avoid getting disturbed sediment in the samples.

1.4.6 Aquatic Biota Sample Collection

Aquatic biota samples were collected in accordance with the procedures described in Section 3.3 of the SW&SMP. Following collection of the aquatic biota samples, sediment samples were collected at each location beginning with the most downstream sample and working progressively upstream. The procedures are described in more detail in Section 7.

1.5 Quality Assurance

Quality assurance / quality control (QA/QC) samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide Quality Assurance Project Plan (QAPP). The following QA/QC samples were collected in 2015.

- Nine equipment rinsate blanks distributed across the monitoring units as follows:
  - Sediment: 1
  - OU-7/OU-10/Basins: 8
- Seven field duplicate samples distributed across the monitoring units as follows:
  - Surface water: 1
  - Sediment: 1
  - OU-7: 2
  - OU-10: 1
  - Basins: 1
  - OU-7/OU-10/Basins: 1
- Seven matrix spike / matrix spike duplicate (MS/MSD) samples distributed across the units as follows:
  - Surface water: 1
  - Sediment: 1
  - OU-7: 2
  - OU-10: 1
  - Basins: 1
  - OU-7/OU-10/Basins: 1

- One trip blank per cooler containing volatile organic compounds (VOC) samples (total of 9 trip blanks).

Groundwater samples were submitted to Eurofins Lancaster Laboratories Environmental, LLC (Lancaster) for analysis of the compounds of potential concern (COPCs) as presented in Section 3.6.1 of the OU-7 GWMP. Surface water and sediment samples were likewise submitted to Lancaster for analysis of the COPCs as presented in Section 2.5 of the SW&SMP. Lancaster performed the analyses using USEPA-approved analytical methods as described in the Site-Wide QAPP, the OU-7 GWMP, and the SW&SMP. Environmental Chemistry Consultants, Inc. (ECCI) performed data review, verification, and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. Data validation reports are provided as Appendix B.

1.6 Report Organization

In addition to this introduction, the report includes the following sections.

- Section 2 presents the results of the OU-7 capture zone groundwater monitoring. It describes the activities associated with the implementation of capture zone water level and groundwater quality monitoring for VB 9-11.
- Section 3 presents the results of the OU-7 post-closure groundwater monitoring. It describes groundwater sampling activities implemented as part of the post-closure maintenance of VB 9-11 conducted in accordance with the VSWMR requirements.
- Section 4 presents the results of the OU-10 post-closure groundwater monitoring. It describes the annual groundwater sampling implemented as part of the post-closure maintenance of OU-10 VB 1-8 and the New Landfill management units.
- Section 5 presents the results of the NTCRA Basins post-closure groundwater monitoring. It summarizes the annual groundwater sampling implemented as part of the post-closure maintenance of the NTCRA Basins Closure Sulfate Basins (SB) and Fly Ash Basins (FAB) management units.
- Section 6 presents the results of the OU-7 surface water and sediment monitoring. It summarizes the annual sampling of the river surface water and sediment implemented in accordance with the SW&SMP.
- Section 7 presents the results of the OU-7 aquatic biota sampling. It summarizes aquatic biota and sediment samples from the South Fork Shenandoah River adjacent to the Avtex Fibers Superfund Site from September 14 to 18, 2015.
- Section 8 provides the references cited in the report.

2.0 OU-7 CAPTURE ZONE GROUNDWATER MONITORING

The OU-7 groundwater monitoring was conducted concurrently with the annual sampling at OU-10 and the NTCRA Basins. Groundwater, surface water, and sediment samples were collected between July 6 and August 6, 2015. The objectives of the OU-7 monitoring, as stated in the OU-7 GWMP, are to:

1. Monitor groundwater elevations and quality to evaluate remedy performance and to support plume capture zone analyses; and
2. Monitor groundwater quality for the closed VB 9-11 units in accordance with the VSWMR.

The activities described herein were completed in accordance with the protocols established by the OU-7 GWMP. Any deviations to the USEPA-approved document are noted.

2.1 Monitoring Well Network

The OU-7 monitoring well network was identified in the OU-7 GWMP and included 72 wells for water level gauging, 53 of which were also to be sampled for groundwater quality monitoring. During the implementation of the OU-7 GWMP in 2013, the well network was revised to accommodate the installation of well nests 605 and 606 (multiple intervals for monitoring) and the installation of well TW-03. The network was further revised in 2014 when wells TW-01, TW-02, and TW-03 were converted to extraction wells.

For the 2015 groundwater sampling event, 74 wells were included in the OU-7 monitoring well network, and 52 of these were sampled for groundwater quality monitoring. The locations of the 74 wells are shown on Figure 2, and the wells are listed below.

Overburden	Shallow Bedrock	Intermediate Bedrock	Deep Bedrock
Sampled Upgradient Wells (seven wells)			
WP-11, 029	103, 128, 133	203	301
Sampled Downgradient Wells (45 Wells)			
005, 024, MW-09, MW-10, WP-10	105, 114, 115, 116R, 132, 138, 162, 185, MW-03R, PZ-06, GM-02A	136, 181, 205, 206, 210, 215, 216, 232, 238, GM-02B, GM-09, PW-0, PW-02	305, 306, 316, 336, 338, 501A, 501B, 501C, 601, 602, 603*, 604*, 605A, 605B, 606A, 606B
Water Level Gauging Only (22 Wells)			
012, 014R, WP-12R	110, 112, 129, 135, MW-06, PZ-03, PZ-05, PZ-09	133-Off, 141, GM-01B, PW-01, PW-04	091, 303, 315, TW-01, TW-02, TW-3

* Wells 603 and 604 are each fitted with FLUTe liners with sample ports in four depth zones.

As previously mentioned, since wells TW-01, TW-02, and TW-03 have been converted to extraction wells, they have been removed from the sampling network. However, water levels are collected from these wells using the value reported to the Groundwater and Leachate Treatment Plant control system by transducers located in each of the three wells.

2.2 Water Level Measurements

Section 2.2 of the OU-7 GWMP required monthly water level monitoring during the baseline period prior to operation of the groundwater recovery system and during the first year of operation of the recovery system. The monthly data established a baseline for groundwater flow directions against which the extent and degree of groundwater capture could be assessed after the recovery system had been started. The need for an additional recovery well across the river in Rivermont Acres could also be assessed from these data. Based on the results of subsequent groundwater capture analysis (ERM 2012), USEPA directed FMC to install the third recovery well in Rivermont Acres (referred to as TW-03) prior to startup of the extraction system. Consequently, monthly water level monitoring was not necessary. Quarterly data are being collected during the baseline period instead.

The first quarterly synoptic water level data for 2015 were collected on March 18, 2015. Three subsequent events followed on July 7 (prior to initiating the annual groundwater sampling event), September 14, and December 8, 2015. Water levels were measured using an electronic water level meter and recorded to the nearest 0.01 foot. Groundwater elevation data are presented on Table 7. The groundwater elevation contours for each monitoring interval (overburden, shallow bedrock, intermediate bedrock, and deep bedrock) are presented separately. Figures 3A, 3B, 3C, and 3D show the groundwater elevation contours for the overburden interval in March, July, September, and December 2015, respectively. Similarly, Figures 4A though 4D; 5A through 5D; and 6A through 6D show the groundwater contour intervals during the same monitoring events in the shallow, intermediate, and deep bedrock intervals, respectively.

Groundwater under the Site (on the east side of the river) generally flows to the west toward the river. However, groundwater within the bedrock aquifer flows parallel to a geologic strike at approximately S30ºW. This flow path represents an approximate 30 degree southward departure from the piezometric gradient. In Rivermont Acres on the west side of the Shenandoah River, groundwater typically flows toward the east and southeast, toward the river. The flow path on the west side of the river is likely attributable to the higher hydraulic heads associated with groundwater recharge in the Catlett Mountains, which lie to the west.

2.3 Capture Zone Analysis

As previously mentioned, the OU-7 monitoring wells were gauged four times during 2015 (March 18, July 7, September 15, and December 8), and there are three operating groundwater recovery wells at the Site (TW-01, TW-02, and TW-03). Extraction wells TW-01 and TW-02 are both screened from (approximately) +200 feet MSL to +460 feet MSL, while TW-03 is screened from (approximately) +15 feet MSL to +335 feet MSL. None of the wells were pumping in January or February. Consistent operation of wells TW-01, TW-02, and TW-03 began in June, March, and August, respectively. Table 8 provides data on the operational history of the three recovery wells during 2015.

Groundwater potentiometric surface maps (Figures 3A through 6D) have been created for the Overburden and the three intervals of the Bedrock (Shallow, Intermediate, and Deep), as they have been previously defined. Interpretation of the groundwater potentiometric maps indicates:

- The Overburden figures (3A through 3D) show a linear effect slightly off-axis to TW-01/TW-02. There are dewatering wells in the overburden in the region of the VBs that would add to any effect pumping from TW-01/TW-02 would have on the overburden.
- The Shallow Bedrock figures (4A through 4D) clearly show the effect of TW-02 pumping and the initial effects of TW-01 pumping (particularly 4B, 4C, and 4D).
- The Intermediate Bedrock figures for July, September, and December (5B, 5C, and 5D, respectively) show a well-defined cone of depression between wells TW-01 and TW-02, and suggest that it extends to the opposite side of the river.
- The Deep Bedrock figures for July, September, and December (6B, 6C, and 6D, respectively) show more variation in monitored water levels; however, there does appear to be a well-defined cone-of-depression between wells TW-01 and TW-02. (there is only about 1 foot of difference in head between well cluster 501, near well TW-03, and well pair 606, located southeast of TW-03).

Maximum site-wide drawdown (as defined as the difference between the March 18 hydraulic heads and those measured in July, September, and December) was observed during the September 15th gauging event (Table 7 includes calculated drawdowns). Maps of hydraulic head drawdown were created using this data for the four subsurface zones (Figures 3E, 4E, 5E, and 6E). Interpretation of the hydraulic head drawdown maps indicates:

- The overburden drawdown (Figure 3E) indicates that there may be more influence on the overburden near well TW-01 than near well TW-02. Up to 1 foot of drawdown may be due to natural seasonal variation.
- The shallow bedrock drawdown (Figure 4E) shows a well-developed cone of depression extending between wells TW-01 and TW-02, and extending across the river. Natural seasonal variation may account for 1 to 2 feet of observed drawdown.
- The intermediate bedrock drawdown (Figure 5E) is similar to the shallow bedrock zone. Natural seasonal variation may account for 2 feet of observed drawdown.
- The deep bedrock drawdown (Figure 6E) also indicates an elongated cone of depression that extends from TW-02 through TW-01 and across the river to TW-03. Drawdown values, however, are more variable, possibly indicating less-well-connected fractures. Natural seasonal variation may account for 2 feet of observed drawdown (including negative drawdown, associated with a rise in water levels).

Four hydrogeologic cross-sections also were created using the hydraulic head data from September and groundwater sample analyses from July 2015. Cross-section A-A’ (Figure 7) runs southwest-to-northeast, from the opposite side of the river, through TW-01 and TW-02, over to the railroad tracks. Cross-section B-B’ (Figure 8) runs north-south through TW-02. Cross-section C-C’ (Figure 9) runs north-south, along the eastern bank of the river, through TW-01. Cross-section D-D’ (Figure 10) runs north-south, along the western bank of the river, through TW-03.

Interpretation of the hydrogeologic cross-sectional flow maps indicate:

- Cross-section A-A’ (Figure 7) shows a nicely defined flow toward TW-02, and clearly shows another zone developing around well TW-01.
- Cross-section B-B’ (Figure 8) shows a well-defined area of capture around TW-02.
- Cross section C-C’ (Figure 9) shows a tighter zone of capture around TW-01. The southernmost region (near C’) is outside of the capture.
- Cross-section D-D’ (Figure 10) shows the effects of pumping from across the river in the central portion of the cross-section. The capture zone created by pumping at TW-03 has now extended to the southeast of TW-03.

Interpretation of capture zones includes determining a “stagnation point” (the downgradient point where there is a groundwater divide; groundwater flows back toward the recovery well, or downgradient away from the well), and a maximum capture zone “width.” These were first determined by reviewing the drawdown maps and potentiometric surface maps. Where the capture zones for TW-01 and TW-02 have combined, there is only one stagnation point downgradient from well TW-01. Capture zones were only interpreted for zones where groundwater recovery is taking place.

- In the shallow bedrock, the stagnation point appears to be on the opposite side of the river, about 1,000 feet downgradient fromTW-01. The maximum capture zone width is around 2,000 feet at TW-02 (i.e., 1,000 feet cross gradient to either side of TW-02) and 600 feet at TW-01.
- In the intermediate bedrock, the stagnation point appears to be on the opposite side of the river, about 800 feet downgradient from TW-01. The maximum capture zone width is around 1,400 feet at TW-02 and 1,200 feet at TW-01.
- In the deep bedrock, the variability in groundwater levels results in a less straightforward determination. The stagnation point appears to be on the opposite side of the river, 800 feet downgradient fromTW-03. The maximum capture zone width is around 1,000 feet at TW-02, 1,600 feet at TW-01, and 600 feet at TW-03.

The USEPA’s capture zone evaluation guidance includes formulas on how to calculate steady-state stagnation points and capture zone widths. However, the underlying assumptions to the equations do not explicitly apply to the Site. Assumptions such as homogeneous and isotropic do not apply to fractured bedrock where the fractures are oriented along a lineament. However, fractured bedrock can be considered homogeneous and isotropic in the “zone” of fractures.

The formulas require hydraulic conductivities, “aquifer” thicknesses, and pumping rates. The site conceptualization presented in the groundwater modeling report (June 2013) was used to determine these values. The original conceptualization included operation of wells TW-01 and TW-02 pumping at a combined 35 GPM. The initial calculations presented below are based on this initial conceptualization.

Because wells TW-01 and TW-02 are screened across all three “layers” (shallow, intermediate, and deep bedrock), the 35 GPM pumping rate was divided across the three intervals based on the weighting of the hydraulic conductivities and layer thicknesses (17% came from the shallow zone, 58% from the intermediate zone, and 25% from the deep zone). Depending on whether the fractured bedrock zones were responding as an unconfined or confined aquifer, the following results were calculated

- Shallow bedrock: stagnation point between 118 feet and 260 feet; maximum capture zone width between 744 feet and 1,636 feet.
- Intermediate bedrock: stagnation point between 183 feet and 264 feet; maximum capture zone width between 1,150 feet and 1,656 feet.
- Deep bedrock: stagnation point between 154 feet and 413 feet; maximum capture zone width between 968 feet and 2,594 feet.

Calculations also indicated that the maximum capture zone should establish itself within 3 weeks. Again, however, this assumes that the fractured bedrock formations act in an equivalent manner as a typical porous media (i.e., sand aquifer).

2.4 Sample Analysis

The analyses performed on each groundwater sample are listed below with the analytical methods identified in the OU-7 GWMP.

- Dissolved metals by USEPA Method 6020A:
    - Aluminum
    - Antimony
    - Arsenic
    - Cadmium
    - Chromium
    - Cobalt
    - Iron
    - Lead
    - Manganese
    - Nickel
    - Vanadium
    - Zinc
- Dissolved mercury by USEPA Method 7470A
- Cyanide (free) by USEPA Method 9014
- VOCs by USEPA Method 8260B:
    - Acetone
    - Carbon disulfide
- Semivolatile organic compounds (SVOCs) by USEPA Method 8270D:
    - 2-Methylphenol (o-Cresol)
    - 4-Methylphenol (p-Cresol)
    - Bis(2-ethylhexyl)phthalate
    - Naphthalene

- Pentachlorophenol
- Phenol

2.5 Quality Assurance

As previously mentioned in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. The following QA/QC samples were collected in 2015 as part of the OU-7 Sampling.

- Eight equipment rinsate blanks distributed across all three monitoring units (OU-7/OU-10/Basins)
- Three field duplicate samples distributed across the monitoring units as follows:
  - OU-7: 2
  - OU-7/OU-10/Basins: 1
- Three matrix spike / matrix spike duplicate (MS/MSD) samples distributed across the units as follows:
  - OU-7: 2
  - OU-7/OU-10/Basins: 1
- One trip blank per cooler containing volatile organic compounds (VOC) samples.

Following laboratory analysis of the samples, ECCI performed a data review, verification, and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The results of the data validation for samples associated with OU-7 are summarized below and the data validation reports are provided as Appendix B.

All OU-7 data were considered usable with one exception: for group SDG AVX05, sample 2015AN-128 provided recoveries of all acid-fraction deuterated monitoring compounds (DMCs) below 10%. The results for all acid-fraction analytes reported as not-detected in the sample are flagged as unusable (R).

Data qualifiers have been added to some of the results. These qualifiers provide additional details regarding the data such as QC issues or interferences. Data qualified with a “J” indicate that, while the constituent was positively identified, the associated numerical value is an estimated concentration. Examples of data that may be qualified with this flag include values below the reporting limit (RL) but above the method detection limit (MDL), or where the associated QC samples are outside acceptable ranges.

With the exceptions noted below, the qualifiers added during the data validation process do not impact any of the decisions made using the data.

- For SDGs AVX02, AVX05, and AVX16, the OU-7 results reported for free cyanide in all samples (wells 114, 115, 116R, 128, 133, 136, 162, 181, 185, 205, 206, 238, 338, 603, 501A, 501B, 605A, 605B, 606B, MW-03R, MW-09, PW-02, PZ-06, and WP-11) are flagged as estimated (J) due to non-compliant MS/MSD precision.

- For SDG AVX02, sample 2015AN-MW-03R provided MS/MSD recoveries of mercury below the lower limit. The positive result reported for this analyte in all samples associated with the SDG (wells 115, 116R, 603, 605A, and MW-03R) are flagged as estimated with the potential for low bias (J-).
- For SDG AVX05, sample 2015AN-128 provided recoveries of all acid-fraction DMCs below 10%. The results for all acid-fraction analytes reported as not-detected in the sample are flagged as unusable (R).
- For SDG AVX07: Samples 2015AN-118, 2015AN-119, 2015AN-119D, 2015AN-120R, and 2015AN-130R were associated with non-compliant continuing calibration verification (CCV) stability for chloromethane and 4-methyl-2-pentanone. The results reported for these analytes in the samples are flagged as estimated (J) to signify the indication of low bias.
- For SDG AVX12, both samples are associated with a non-compliant CCV for pentachlorophenol. The results reported for this analyte in them are flagged as estimated (J) to signify the indication of low bias (PW-0 and PW-0 duplicate sample).
- For SDG AVX15, sample 2015AN-MW-10 provided non-compliant neutral-fraction DMC recovery. The results reported for bis(2-ethylhexyl)phthalate and naphthalene in the sample are flagged as estimated (J) to signify the indication of low bias.
- For SDG AVX16:
  - Samples 2015AN-MW-09, 2015AN-PW-02, and 2015AN-PZ-06 were associated with a non-compliant CCV for aluminum. The positive results reported for this element in all three samples are flagged as estimated (J) to signify the indication of high bias.
  - Sample 2015AN-WP-11 provided non-compliant MS/MSD recoveries of mercury. The results reported for this analyte in all OU-7 samples associated with the SDG (wells 114, 205, 238, 338, MW-09, PW-02, PZ-06, and WP-11) are flagged as estimated with the potential for low bias (J-).

The data quality objectives (DQOs) for the post-closure monitoring are to provide data of sufficient quality to evaluate changes in groundwater quality over time, if any, associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and the SW&SMP, definitive quantitation of the concentrations of constituents of potential concern in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQO.

The monitoring plan calls for sampling 56 wells at OU-7. Each sample is analyzed for 22 constituents (13 metals, cyanide, two VOCs, and six SVOCs) for a total of 1,232 individual constituent results. Three of the results were rejected; therefore, definitive quantitation for 99.8% of the constituents was achieved.

2.6 Results

The validated groundwater sample results for 2015 are presented in Table 9 and summarized in the following subsections. Laboratory reports are provided in Appendix C. Historical results are provided in Appendix D.

2.6.1 VOCs

Acetone was detected at relatively low concentrations in eight monitoring wells (215, 238, 305, 336, 604-Z4, 605B, MW-09, and WP-11). None of the detected concentrations exceeded the OU-7 cleanup standard of 22,000 micrograms per liter (µg/L). In 2014, acetone was detected at similarly low concentrations in six wells: 116R, 216, 336, 605B, MW-09, and WP-11.

Carbon disulfide was detected in 32 of the sampled wells and appeared in each of the four flow zones (overburden, shallow bedrock, intermediate bedrock, and deep bedrock). The detected concentrations exceeded the OU-7 cleanup standard of 1,000 µg/L in five wells (205, 206, 305, 336, and MW-03R). This is a significant decrease from 2014, when carbon disulfide was detected in 34 wells and exceeded the standard in 11 of the wells (138, 206, 215, 216, 305, 316, 336, 603-Z1, MW-03R, MW-09, and PW-02).

The results are discussed by monitoring zone in more detail below.

Overburden

- Within the overburden flow zone, the maximum concentration of carbon disulfide was detected at well MW-09, located along the western edge of VB 9. The concentration at well MW-09 was significantly less than the concentrations detected in since 2012 as shown below.

Well	2012	2013	2014	2015
MW-09R	5,450 µg/L	1,110 µg/L	1,210 µg/L	750 µg/L

- At downgradient well 024, the carbon disulfide result was reported as not detected (consistent with past results).

Shallow Bedrock

- Within the shallow bedrock zone, carbon disulfide was detected above the OU-7 cleanup standard in one well (MW-03R) at a concentration of 2,600 µg/L. This well is in the heart of OU-7 between VB 9 and VB 11. The carbon disulfide concentration at this well continues to decrease as compared to the results from the 2013 and 2014 sample events.
- Carbon disulfide was not detected above the cleanup standard in any other wells in this zone.
- In addition to MW-03R, carbon disulfide has historically been detected at concentrations above the cleanup standard in shallow bedrock wells116R and 138. However, the concentrations in these wells continues to decrease as shown below.

Year	116R	138	MW-03R
2013	172 µg/L	2,690 µg/L	6,930 µg/L
2014	183 µg/L	1,310 µg/L	4,290 µg/L
2015	57 J µg/L	138 µg/L	2,600 µg/L

Intermediate Bedrock

- Carbon disulfide was detected in groundwater above the OU-7 cleanup standard at two wells: 205 and 206.
- The elevated concentration of carbon disulfide at well 206, located on the west side of the river, is consistent with previously observed bedrock fracture flow at the Site.
- The concentration at well 205 has been increasing since 2013 but remains below historic concentrations.
- In 2014, carbon disulfide exceeded the cleanup standard in four intermediate bedrock wells (206, 215, 216, and PW-02). However, as shown below, the concentrations in these wells is now below the cleanup standard.

Year	205	206	215	216	PW-02
2012	9,450 µg/L	11,600 µg/L	648 J µg/L	2,960 J µg/L	9.3 µg/L
2013	203 µg/L	12,000 L µg/L	1,400 µg/L	5,320 µg/L	50.4 µg/L
2014	90.5 µg/L	8,100 µg/L	1,230 µg/L	3,940 µg/L	1,920 µg/L
2015	1,300 µg/L	7,500 µg/L	930 µg/L	1,000 µg/L	180 µg/L

L = Reported value may be biased high.
J = Estimated result.

Deep Bedrock

- Carbon disulfide was detected in the deep bedrock flow zone above the OU-7 cleanup standard at two wells: 305 and 336.
- In 2014, four wells had concentrations of carbon disulfide exceeding the cleanup standard (305, 316, 336, and 603-Z1). However, as shown below, wells 316 and 603-Z1 did not exceed the criteria in 2015.

Year	305	316	336	603-Z1
2013	39,900 µg/L	4,540 µg/L	9,690 µg/L	1,180 J µg/L
2014	41,100 µg/L	7,180 µg/L	10,200 µg/L	1,860 µg/L
2015	28,000 µg/L	520 µg/L	14,000 µg/L	98 µg/L

2.6.2 SVOCs

The only SVOC detections above the OU-7 cleanup standards were at overburden monitoring well MW-09. Two SVOCs (4-methylphenol and phenol) were detected in groundwater at this location at concentrations of 190 µg/L and 25,000 µg/L, respectively which exceeds the cleanup standards for these constituents of 180 µg/L and 11,000 µg/L, respectively. Consistent with recent historical results, SVOCs were not detected above the OU-7 cleanup standards in the shallow, intermediate, or deep groundwater.

2.6.3 Inorganic Constituents

Nine metals (antimony, arsenic, chromium, cobalt, iron, lead, manganese, nickel, and vanadium) were reported at concentrations exceeding their respective OU-7 cleanup standards in at least one monitoring well (Table 9). Aluminum, cadmium, mercury, and zinc were not detected in any sample above their OU-7 groundwater cleanup standards. The results are discussed by monitoring zone in more detail below.

Overburden

- At MW-09, which is near VB 9, antimony, arsenic, chromium, cobalt, nickel, and vanadium were reported at concentrations above the OU-7 groundwater cleanup standards. This is consistent with historic results at this location.
- At WP-10, which is along the northern side of VB 9, arsenic and cobalt were detected above their respective OU-7 groundwater cleanup standards. This is consistent with the results from 2013 and 2014.
- At MW-10, downgradient of VB 10, arsenic, cobalt, iron, and manganese were detected at concentrations that exceeded their respective OU-7 groundwater cleanup standards. The arsenic and cobalt results are consistent with historic results for this well, while the iron and manganese concentrations are several orders of magnitude higher than recent concentrations measured at this location. The reason for the increase in iron and manganese concentrations is not clear. Turbidity and other field parameters were not significantly different from past results.
- Consistent with 2013 and 2014, manganese was also detected at upgradient well WP-11 at a concentration exceeding the OU-7 groundwater cleanup standard.
- Downgradient well 005 was dry and, therefore, no sampled could be obtained from this location. This is evidence of the drawdown being created by pumping at the adjacent extraction well, TW-01.
- Cyanide was not detected in any of the overburden groundwater monitoring wells at a concentration exceeding the OU-7 groundwater cleanup standard. While cyanide has historically been detected above the cleanup standard at well MW-09, it was below the standard in 2014 and not detected in 2015.

Shallow Bedrock

- Manganese was detected at concentrations exceeding the OU-7 groundwater cleanup standard in five of the 14 wells sampled (103, 105, 114, 128, and 132). These wells represent both upgradient (103, 128, and 132) and downgradient (105 and 114) conditions. At all five wells, manganese was the only inorganic constituent detected above an OU-7 groundwater cleanup standard. The manganese results are similar to those reported in 2013 and 2014.
- At well 116R the following inorganic constituents were detected at concentrations exceeding their OU-7 groundwater cleanup standards: antimony, arsenic, cobalt, and nickel. Chromium and cyanide have historically been detected at this location above their OU-7 cleanup standards; however, the concentrations have been decreasing. Chromium has not exceeded the standard since 2014 and chromium did not exceed the standard in 2015. The remaining results are similar to historic results.
- Arsenic and cobalt were the only constituents detected at a concentration exceeding an OU-7 groundwater cleanup standard at upgradient well 133. The arsenic concentration has remained relatively stable at this well. The cobalt concentration has fluctuated over the years from a low of 3.9 µg/L (2012) to a high of 16.4 µg/L (2013).

- At well 138 arsenic and cobalt were detected in groundwater at concentrations exceeding the OU-7 cleanup standard. These results are similar to those reported in historic sampling events.
- At well GM-02A, which is downgradient and across the Shenandoah River, only arsenic exceeded the cleanup standard. The concentrations of other constituents historically detected at this well exceeding the standard (antimony, cobalt, and cyanide) have all decreased.
- At well MW-03R antimony, arsenic, and cobalt were detected at concentrations exceeding the OU-7 groundwater cleanup standard. The concentrations are consistent with historic results. Chromium, manganese, nickel and cyanide have also historically been detected above the cleanup standards at this location. Manganese last exceeded the standard in 2014; while mercury, nickel, and cyanide have not exceeded the standards since 2000.
- No inorganic constituents were detected at concentrations exceeding their OU-7 groundwater cleanup standards at wells: 115, 162, 185, and PZ-06.
- Cyanide was not detected in any of the shallow bedrock groundwater monitoring wells at a concentration exceeding the OU-7 groundwater cleanup standard.

Intermediate Bedrock

- Antimony, arsenic, and cobalt were detected in groundwater at concentrations exceeding their OU-7 groundwater cleanup standard at downgradient wells 205, 206, 216, and GM-02B.
- Concentrations at downgradient well PW-02 continue to decrease or remain stable. The only constituent detected above the OU-7 groundwater cleanup standard in 2015 was arsenic. Historically, antimony, arsenic, cobalt, and cyanide have been detected at this location at concentrations exceeding the cleanup standard. The lack of detectable cyanide at this location in 2015 is likely due to laboratory issues that resulted in an elevated detection limit.
- The highest concentrations of dissolved arsenic continues to be reported at wells 205 (downgradient of the SBs) and GM-02B (located downgradient and across the Shenandoah River).
- Consistent with historical results, antimony and arsenic were detected in groundwater at well 238 at concentrations exceeding the OU-7 cleanup standard. Historically, cobalt has also been detected above the cleanup standard at well 238, but it has not been detected above the standard since 2013.
- At downgradient wells GM-09R and PW-0, only manganese was detected at concentrations exceeding the OU-7 groundwater cleanup standard. The results at PW-0 are consistent with past sampling events. Various metals have been sporadically detected above their cleanup standards at GM-09R in the past.
- No inorganic constituents were detected at concentrations exceeding their OU-7 groundwater cleanup standards at wells 136, 181, 203, 210, 215, and 232.
- Cyanide was not detected in any of the intermediate bedrock groundwater monitoring wells at a concentration exceeding the OU-7 groundwater cleanup standard.

Deep Bedrock

- Antimony, arsenic, and cobalt were detected in groundwater at concentrations exceeding their OU-7 groundwater cleanup standard at downgradient wells 305, 316, and 336. In addition, lead was detected in groundwater at well 336 at a concentration exceeding the OU-7 groundwater cleanup standard.
- The highest concentrations of dissolved inorganics continue to be observed at well 305, in the area of the VBs and SBs. Antimony and cobalt concentrations have remained relatively stable at this location; however, arsenic concentrations have increased slightly. Cyanide concentrations have also decreased at this well. However, the lack of detectable cyanide at this location in 2015 is likely due to laboratory issues that resulted in an elevated detection limit.
- Arsenic was the only constituent detected in groundwater at concentrations exceeding an OU-7 groundwater cleanup standard at wells 306, 338, 603-Z1, 603-Z2, 603-Z3, 603-Z4, and 605A. Trends at each of these wells is summarized below.
    - Well 336: arsenic concentrations continue to decrease at this well. Cobalt concentrations have also decreased and this constituent has not been detected above the cleanup criteria since 2013.
    - Well 338: arsenic concentrations continue to decrease at this well. Antimony and cobalt concentrations also continued to decrease and no longer exceed the criterial.
    - Well 603: various metals have been sporadically detected at concentrations exceeding the cleanup criteria at this well.
    - Well 605A: arsenic continues to be sporadically detected above the cleanup standard; while the antimony concentration continues to decrease, and is now below the cleanup criteria. Inorganic constituent concentrations in this well continue to decrease or remain relatively stable.
- The pH of groundwater at well 605 remains slightly elevated but continues to decrease. The pH measured in this well was 11.98 in September 2013, 11.66 in November 2013, 10.44 in July 2014, and 9.71 in July 2015. Similarly, the specific conductivity continues to decrease (2.439 miliSiemens per centimeter [mS/cm]) in September 2013, 1.385 mS/cm in November 2013, 0.87 mS/cm in July 2014, and 0.6 mS/cm in July 2015). Both the pH and specific conductivity values in well 605A have been above the values measured in other wells within the leading edge of the OU-7 plume, suggesting that grout entered the well screen during installation of the nested wells. The presence of grout in the well screen would cause pH and dissolved solids to be elevated and the concomitant leaching of antimony and arsenic from the bedrock. However, these values appear to have returned to normal as the grout has cured.
- No inorganic constituents were detected at concentrations exceeding their OU-7 groundwater cleanup standards at wells 301, 501A, 501B, 501C, 601, 602, 604 (Z1, Z2, Z3, and Z4), 605B, 606A, and 606B.
- Cyanide was not detected at a concentration exceeding the OU-7 groundwater cleanup standard in any of the deep bedrock groundwater monitoring wells.

2.7 Plume Delineation

Figures 11, 12, 13, and 14 present the groundwater elevation maps for each bedrock interval (overburden, shallow, intermediate, and deep, respectively) over which the isoconcentration contours for arsenic, antimony, and carbon disulfide have been superimposed. The arsenic, antimony, and carbon disulfide plumes are shown in blue, green, and pink, respectively, on these maps. A summary of the status of each of these plumes by groundwater zone is presented below.

Carbon Disulfide

- Overburden (Figure 11): carbon disulfide was not detected in the overburden groundwater at concentrations above the OU-7 groundwater cleanup standard of 1,000 µg/L. In 2014, the exceedances were limited to the area around MW-09 (immediately adjacent to and downgradient of VB 9).
- Shallow Bedrock (Figure 12): carbon disulfide was not detected in the shallow bedrock groundwater at concentrations above the OU-7 groundwater cleanup standard. In 2014, exceedances were limited to the area under and immediately downgradient of VBs 9, 10, and 11.
- Intermediate Bedrock (Figure 13): the carbon disulfide plume has narrowed considerably since pumping began and has shortened at both the upgradient and downgradient ends since pumping began.
- Deep Bedrock (Figure 14): the carbon disulfide plume in the deep bedrock groundwater extends from the VBs to the west side of the river. The concentration of carbon disulfide continues to decrease at well 306. The concentration also decreased in the source area, with well 316 now below the cleanup criteria. Carbon disulfide continues to be detected at low concentrations well below the OU-7 groundwater cleanup standard at nested wells 605A and 605B, but was not detected in wells 501A, 501B, 501C. As with the intermediate bedrock zone, the carbon disulfide plume has narrowed considerably and shortened at both the upgradient and downgradient ends since pumping began.

Inorganic Constituents

Arsenic and antimony are the two most widespread inorganic constituents in groundwater at OU-7 and serve as reasonable indicator constituents for delineating the extent of all inorganic constituents.

- Overburden (Figure 11): the antimony plume in shallow bedrock groundwater is limited to the area under and immediately downgradient of VBs 9, 10, and 11. The arsenic plume is slightly more widespread, extending several hundred feet further downgradient. The concentrations of both constituents are similar to those detected in past events and the plume extents are relatively unchanged from 2014.
- Shallow Bedrock (Figure 12): the extent of antimony in shallow bedrock groundwater has decreased, and the plume is now limited to the area under and immediately downgradient of VB 9, 10, and 11. Antimony was not detected in any of the shallow bedrock wells west of the Shenandoah River. The arsenic plume also continues to shrink, with the leading edge near PZ-06 and well 105 on the east side of the river. Only one exceedance of arsenic was observed west of the

river at well GM-02A. The concentration in this well decreased by an order of magnitude compared to 2014 results.

- Intermediate Bedrock (Figure 13): the detected concentrations of arsenic, antimony and other metals at well GM-02B result from the preferential flow of the plume along the bedrock strike. The leading edge of the plumes turn south toward well 206 once west of the river. The plumes extend just north of nested well location 501. Concentrations are reported below OU-7 cleanup standards in groundwater at that location. The plumes narrowed somewhat compared to the results from 2014, but are otherwise similar.
- Deep Bedrock (Figure 14): similar to the intermediate bedrock, the plumes flow to the southwest parallel to the bedrock strike before moving southward once west of the river. The leading edge of the plume, as defined by the OU-7 cleanup standards, has been confirmed to the southernmost extent by well nest 606. The plumes are similar to past results.

2.8 Conclusions

Key findings associated with the 2015 groundwater quality data for OU-7 are summarized below:

- Concentrations of carbon disulfide have shown a noticeable decrease since groundwater extraction began.
- Carbon disulfide concentrations at all of the overburden~~shallow bedrock~~ wells are below the OU-7 groundwater cleanup standard and only one shallow bedrock well exceeds the cleanup standard, indicating that the plume has quickly attenuated in the overburden and shallow bedrock zones.
- The leading edge of the carbon disulfide plume is still located across the Shenandoah River. However, the plume has narrowed considerably and shortened at both the upgradient and downgradient ends since pumping began.
- Concentrations of inorganic constituents in bedrock groundwater are consistent with prior monitoring events and indicate that the groundwater plumes in the overburden, shallow, intermediate and deep bedrock flow zones are stable or decreasing in concentration.
- Various metals are present in the shallow bedrock flow zone above the OU-7 cleanup standards. However, only antimony, arsenic, cobalt and lead concentrations exceed the OU-7 groundwater cleanup standards in shallow bedrock wells on the west side of the river (wells 206, 336, and GM-02B).
- For the third consecutive year, there were no exceedances of the OU-7 groundwater cleanup standards in wells 501A, B and C. Similarly, there were no exceedances of the OU-7 groundwater cleanup standards in wells 606A and 606B.
- The capture zone analysis indicates that:
  - There is a well-developed cone of depression in the shallow and intermediate bedrock between wells TW-01 and TW-02 and extending across the river.
  - The deep bedrock drawdown also indicates an elongated cone of depression that extends from TW-02 through TW-01 and across the river

to TW-03. However, drawdown values are more variable in this zone, possibly indicating less well-connected fractures.

- The effects of pumping from across the river are evident, and the capture zone created by pumping at TW-03 has now extended to the southeast of TW-03.

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3.0 OU-7 POST-CLOSURE GROUNDWATER MONITORING

This section summarizes groundwater quality monitoring for the closed VB 9-11 units in accordance with the VSWMR groundwater monitoring requirements under 9VAC 20-80-270D and 9VAC 20-80-300 for closure of industrial waste disposal facilities. It presents the results of the 2015 annual groundwater sampling event implemented in July and August as part of the post-closure maintenance of VB 9-11. Figure 15 shows the layout of VB 9-11 and the location of the 11 OU-7 VSWMR monitoring wells. The purpose of the post-closure groundwater monitoring of these units is to determine whether groundwater quality continues to degrade and, if so, whether an unacceptable risk is posed by the change in water quality conditions. Only the uppermost groundwater quality in the overburden and shallow bedrock is monitored.

The baseline sampling for this unit was completed in December 2014, and control charts have been developed. These charts are used to compare the July 2015 and future results to determine whether groundwater quality in the downgradient monitoring wells is degraded relative to the baseline conditions.

3.1 Monitoring Well Network

VBs 9-11 form a relatively contiguous management unit of over 9.8 acres along the north portion of the Site west of the railroad tracks. Eleven wells have been identified as the monitoring network for the post-closure monitoring of these basins, meeting the intent of the VSWMR. Figure 15 shows the locations of the monitoring wells, and Table 1 summarizes the construction details for the wells. The current monitoring well network for VB 9-11 is listed below.

Overburden	Shallow Bedrock
Upgradient (four Wells)	
029, WP-11	128, 133
Downgradient (seven Wells)	
MW-09, WP-10, 024	105, 116R, 138, PZ-06

3.2 Water Level Measurements

In accordance with the OU-7 GWMP, synoptic water level measurements were obtained during each sampling event prior to purging and sampling of the monitoring wells. Water levels were measured using an electronic water level meter and recorded to the nearest 0.01 feet in the bound field book dedicated for the sampling activities. Table 7 summarizes the elevation data obtained for each well measured during the July 2015 event. The groundwater contours for both the overburden and the shallow bedrock are shown on Figures 3B (overburden June 2015) and 4B (Shallow Bedrock June 2015).

Piezometric gradients in the overburden (Figure 3B) and bedrock (Figure 4B) are generally west toward the river, perpendicular to the contour lines. A linear effect slightly off-axis to pumping wells TW-01/TW-02 visible on Figure 3B is the result of groundwater extraction. The Shallow Bedrock map (Figure 4B) also clearly shows the effect of pumping at wells TW-01 and TW-02.

3.3 Sample Analysis

The analyses performed on each groundwater sample and the analytical methods are listed below. The analytical methods were identified in the OU-7 GWMP.

- Dissolved metals by USEPA Method 6020A:
    - Aluminum
    - Antimony
    - Arsenic
    - Cadmium
    - Chromium
    - Cobalt
    - Iron
    - Lead
    - Manganese
    - Nickel
    - Vanadium
    - Zinc
- Dissolved mercury by USEPA Method 7470A
- Cyanide (free) by USEPA Method 9014
- VOCs by USEPA Method 8260B:
    - Acetone
    - Carbon disulfide
- SVOCs by USEPA Method 8270D:
    - 2-Methylphenol (o-Cresol)
    - 4-Methylphenol (p-Cresol)
    - Bis(2-ethylhexyl)phthalate
    - Naphthalene
    - Pentachlorophenol
    - Phenol

3.4 Quality Assurance

As discussed in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. Following laboratory analysis of the samples, ECCI performed data review, verification and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The results of the data validation are summarized in Section 2.5, and the data validation reports are provided as Appendix B.

The DQOs for the post-closure monitoring are to provide data of sufficient quality to evaluate changes in groundwater quality over time, if any, associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and in the SW&SMP, definitive quantitation of the concentrations of COPCs in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQO.

The monitoring plan calls for sampling 11 wells at OU-7. Each sample is analyzed for 22 constituents (13 metals, cyanide, two VOCs, and six SVOCs) for a total of 242 individual constituent results. Because three of the results were rejected, definitive quantitation was achieved for 98.76% of the constituents.

3.5 Results

The validated groundwater sample results for 2015 are presented in Table 10 and summarized in the following subsections. Laboratory reports are provided in Appendix C.

3.5.1 Upgradient Overburden Wells

Overburden monitoring wells 029 and WP-11 are intended to represent water quality conditions upgradient of VB 9-11 (background). The results from these wells are summarized below.

- One VOC (acetone) was detected at WP-11 in 2015. The concentration at this location is well below the 22,000 µg/L OU-7 groundwater cleanup standard, but is above the established baseline of 13.4 µg/L. Acetone has been sporadically detected in this well during past sampling events.
- Carbon disulfide was not detected in either well.
- No SVOCs were detected in either well.
- Several metals were detected in one or both of the wells; however, only manganese was detected above the groundwater cleanup standard. Consistent with previous sampling results, the manganese concentration at well WP-11 (1,590 µg/L) exceeded the groundwater cleanup criteria of 880 µg/L. The concentration also exceeds the established baseline for this location of 1,240 µg/L.
- The iron concentration at WP-11 (13,100 µg/L) also exceeded its baseline of 11,300 µg/L, but does not exceed the cleanup standard of 26,000 µg/L.
- No constituents above the cleanup standard or the baseline concentrations were detected in well 029.
- Cyanide was not detected in groundwater at either of the wells.

3.5.2 Downgradient Overburden Wells

The three overburden wells located downgradient of VB 9-11 are 024, MW-09, and WP-10. The results from these wells are summarized below.

- Acetone was detected in groundwater at well MW-09; however, the concentration (2,800 µg/L) was below the OU-7 groundwater cleanup criteria (22,000 µg/L) and the baseline established at this location (2,970 µg/L).
- Carbon disulfide was detected at wells MW-09 and WP-10; however, the concentrations (750 µg/L and 36 µg/L, respectively) are below the groundwater cleanup standard (1,000 µg/L) and the baselines established for these wells (1,210 µg/L and 107 µg/L, respectively).
- Three SVOCs (2-methylphenol, 4-methylphenol, and phenol) were detected in groundwater at well MW-09 and two SVOCs (naphthalene and O-cresol) were detected at well WP-10. Of these, only two (4-methylphenol and phenol) were detected above the associated cleanup standard (at well MW-09). Both constituents also exceeded the baseline concentrations established for this location.
- No SVOCs were detected at well 024.
- Inorganic results:
  - Aluminum was not detected above the cleanup standard in any of the samples, and all concentrations were near or below the established baselines.
  - Antimony was detected in groundwater at well MW-09 at a concentration of 74.3 µg/L which exceeds the OU-7 groundwater cleanup standard of 6 µg/L but is lower than the baseline of 82.6 µg/L. Antimony was not detected in groundwater at well 024 and was detected at a relatively low concentration of 0.49 J µg/L at well WP-10.
  - Arsenic was detected in groundwater at wells 024, MW-09, and WP-10 at concentrations of 1.2 J µg/L, 2,480 µg/L, and 182 µg/L, respectively. The concentration at well 024 is below the cleanup standard of 10 µg/L and essentially equal to the baseline of 1.1 µg/L. Consistent with past sampling events, the concentrations detected at wells MW-09 and WP-10 are above the cleanup standard. The arsenic concentration at well MW-09 is slightly above the baseline of 2,180 µg/L.
  - Cadmium was not detected above the cleanup standard in any of the samples, and all concentrations were near or below the established baselines.
  - Chromium was detected in groundwater at well MW-09 at a concentration of 144 µg/L, which exceeds the groundwater cleanup standard (100 µg/L) and is slightly above the baseline of 119 µg/L. Chromium was detected at well WP-10 at a concentration (11.8 µg/L) below the baseline concentration (12.5 µg/L). Chromium was not detected in well 024.
  - Cobalt was detected at concentrations above the cleanup standard of 11 µg/L at wells MW-09 and WP-11 (at 758 µg/L and 174 µg/L, respectively). The detected concentrations also slightly exceeded their baselines of 637 µg/L and 174 µg/L, respectively.
  - Iron was not detected above the cleanup standard in any of the samples, and all concentrations were near or below the established baselines.

- Lead and manganese were not detected above the cleanup standard in any of the samples, and all concentrations were below the established baselines.
- Mercury was not detected in any of the samples.
- The nickel concentration at well MW-09 (2,140 µg/L) exceeds the groundwater cleanup standard of 730 µg/L and the baseline of 1,640 µg/L. Nickel concentrations at wells 024 and WP-10 were below both the cleanup standard and the baseline values.
- Vanadium was detected in groundwater at MW-09 (619 µg/L) above the OU-7 groundwater cleanup standard of 260 µg/L and the baseline for this well of 476 µg/L. Vanadium was not detected above the cleanup standard or baseline values in wells 024 and WP-10
- Zinc was not detected in any of the samples above the cleanup standard and all concentrations were near or below the established baselines.
- Cyanide was detected at a concentration of 13.3 J µg/L at well WP-10 (below both the cleanup standard and baseline). Cyanide was not detected in wells 024 and MW-09.

- The pH reported for wells MW-09 and WP-10 ranged from 9.32 to 9.44 (similar to past results). The groundwater at these wells also exhibited a relatively high conductivity and contained essentially no dissolved oxygen. Groundwater at well 024 was more neutral with a pH of 7.27, lower conductivity, and considerably higher dissolved oxygen.

3.5.3 Upgradient Shallow Bedrock Wells

Upgradient groundwater quality in the shallow bedrock aquifer is monitored by wells 128 and 133. The results from these wells are summarized below.

- Carbon disulfide was detected in groundwater at well 133 at a relatively low concentration of 8.6 µg/L (below the cleanup standard of 1,000 µg/L, but slightly above the baseline of 3.3 µg/L). Carbon disulfide was not detected in well 128.
- No other VOCs or SVOCs were detected in these two wells.
- Several inorganic constituents were detected in groundwater at the two upgradient shallow bedrock wells. The results are summarized below.
    - Aluminum, antimony, cadmium, lead, mercury, and zinc were not detected in either well.
    - The following constituents were detected but did not exceed their respective OU-7 groundwater cleanup standards: cobalt, iron, and nickel (well 128) and chromium, iron, manganese, nickel, and vanadium (well 133).
    - Arsenic was detected at well 133 (30.7 µg/L) above the OU-7 groundwater cleanup standard of 10 µg/L and the baseline of 15.6 µg/L. Arsenic was not detected at well 128.
    - Cobalt was detected at well 133 at a concentration of 16.4 µg/L, which exceeds the OU-7 groundwater cleanup standard of 11 µg/L but is below

the baseline of 16.4 µg/L. Cobalt was also detected in well 128 (0.34 J µg/L), but the concentration is below both the baseline and cleanup standard.

- Manganese was detected in groundwater at wells 128 and 133 at concentrations of 994 µg/L and 782 µg/L, respectively. The concentration at well 128 exceeds the OU-7 groundwater cleanup standard of 880 µg/L but is below the baseline of 1,170 µg/L. The concentration at well 133 is below the baseline of 1,180 µg/L.
- Cyanide was not detected in either of the samples.

3.5.4 Downgradient Shallow Bedrock Wells

The water quality in the shallow bedrock downgradient of VB 9-11 is monitored by wells 105, 116R, 138, and PZ-06. The results from these wells are summarized below.

- Carbon disulfide was detected in groundwater at wells 105, 116R, and 138. However, none of the concentrations exceeded the OU-7 groundwater cleanup standard or baseline concentrations.
- Acetone was not detected in groundwater at any of the wells.
- None of the six SVOC constituents were detected at concentrations exceeding the OU-7 groundwater cleanup standards.
- The results for inorganic constituents are summarized below.
    - Cadmium and lead were not detected in any of the wells.
    - Aluminum, iron, mercury, vanadium, and zinc were detected in at least one sample, but concentrations did not exceed the respective OU-7 groundwater cleanup standards or baseline concentrations.
    - Antimony was detected in groundwater at well 116R at a concentration (33.2 µg/L) exceeding the OU-7 groundwater cleanup standard of 6 µg/L but below the baseline of 336 µg/L. Antimony was also detected at well 138, but the concentration was below the cleanup standard and baseline concentration.
    - Arsenic was detected in groundwater at wells 116R and 138 at concentrations (416 µg/L and 56.3 µg/L, respectively) exceeding the OU-7 groundwater cleanup standard of 10 µg/L. Arsenic was also detected at wells 105 and PZ-06 at concentrations (4.3 µg/L and 8.2 µg/L, respectively) below the cleanup standard. All four results are below their respective baseline concentrations.
    - Detected chromium concentrations were below the cleanup standard and baseline concentrations at all four wells.
    - Cobalt was detected in groundwater at wells 116R and 138 at concentrations (51.4 µg/L and 22.2 µg/L, respectively) exceeding the OU-7 groundwater cleanup standard of 11 µg/L. Cobalt was also detected at wells 105 and PZ-06 at concentrations below the cleanup standard (0.53 J µg/L and 0.45 J µg/L, respectively). All four results are below their respective baseline concentrations.

- Manganese was detected in groundwater at well 105 at a concentration (1,140 µg/L) exceeding the OU-7 groundwater cleanup standard of 880 µg/L. Manganese was also detected at wells 116R, 138, and PZ-06, but the concentrations were below the cleanup standard. With the exception of well 138, all detected manganese concentrations were below their respective baseline concentrations. The manganese concentration at well 138 (364 µg/L) is above the baseline of 233 µg/L.
- Nickel was detected in groundwater at well 116R at a concentration (1,820 µg/L) exceeding the OU-7 groundwater cleanup standard of 730 µg/L. Nickel was also detected in wells 105, 138, and PZ-06, but at concentrations below the cleanup standard. All nickel concentrations were below their respective baseline concentrations.
- Cyanide was not detected in any of the four wells.

- Similar to previous results, the pH reported for well 116R was slightly elevated (9.28). The groundwater at this well also contained essentially no dissolved oxygen.

3.6 Control Charts

In accordance with the OU-7 GWMP, the control chart approach has been selected as the method to evaluate the data collected in each downgradient well. A control chart is a plot of concentration versus time, with an established concentration limit for baseline that, if exceeded, will indicate an increase in concentration over the baseline. Baseline concentrations for each parameter at each well were established from the initial four semi-annual sampling results conducted in 2013 and 2014. For detected constituents, the baseline is equal to the maximum detected value. For non-detect results, the average detection limit is used as the baseline. However, samples with significantly elevated detection limits (e.g., due to matrix interference or required dilutions) were excluded from the average calculation. Results with “B” or “R” qualifiers are considered invalid or unusable and were therefore also not included in the baseline. The baseline concentration for each constituent is shown next to the reported results on Table 10.

Control charts were developed for each downgradient well except well 024 (no exceedances of the OU-7 groundwater cleanup criteria have been observed at this well). A separate control chart was created for each constituent exceeding the respective OU-7 cleanup criteria at each well during the baseline period. Additional control charts have been added for constituents exceeding the criteria during the current event (e.g., 4-methylphenol at well MW-09). The charts also show the downgradient baseline value and average concentration. Non-detect results are plotted at one-half the RL. The control charts are included in Appendix E. The following control charts were generated:

- MW-09: carbon disulfide, pentachlorophenol, phenol, 4-methylphenol (P-cresol), antimony, arsenic, cadmium, chromium, cobalt, nickel, vanadium, and cyanide
- WP-10: naphthalene, arsenic, and cobalt
- 105: manganese
- 116R: antimony, arsenic, cadmium, chromium, cobalt, nickel, and cyanide
- 138: carbon disulfide, antimony, arsenic, and cobalt
- PZ-06: arsenic and manganese

The control charts were reviewed to determine if the above constituents indicated signs of increasing concentrations. The results are summarized below:

- MW-09
  - Carbon disulfide: Figure E-1 shows that the upgradient and downgradient concentrations have remained stable.
  - Pentachlorophenol was not detected in either MW-09 or the upgradient well WP-11 (Figure E-2).
  - 4-Methylphenol (P-cresol) and phenol: As shown on Figures E-3 and E-4, these two constituents were detected at concentrations (190 µg/L and 25,000 µg/L, respectively) above the established baseline concentrations (80.8 µg/L and 17,300 µg/L, respectively). However, additional data are required to establish a statistically significant trend showing an increase of these constituents in groundwater.
  - Antimony: Figure E-5 shows the upgradient and downgradient concentrations have remained stable.
  - Arsenic: As shown on Figure E-6, arsenic was detected in 2015 at a concentration (2,480 µg/L) slightly above the baseline concentration of 2,180 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
  - Cadmium: The cadmium concentration at MW-09 decreased significantly and remains below the baseline concentration (Figure E-7).
  - Chromium: As shown on Figure E-8, cadmium was detected in 2015 at a concentration (144 µg/L) slightly above the baseline concentration of 119 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
  - Cobalt: As shown on Figure E-9, cobalt was detected in 2015 at a concentration (758 µg/L) slightly above the baseline concentration of 637 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
  - Nickel: As shown on Figure E-10, nickel was detected in 2015 at a concentration (2,140 µg/L) slightly above the baseline concentration of 1,640 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
  - Vanadium: As shown on Figure E-11, vanadium was detected in 2015 at a concentration (619 µg/L) slightly above the baseline concentration of 476 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
  - Cyanide: The cyanide concentration at MW-09 decreased significantly and remains below the baseline concentration (Figure E-12).

- WP-10
  - Naphthalene and arsenic: The naphthalene and arsenic concentrations detected at WP-10 were below the baseline concentrations for these constituents (Figures E-13 and E-14).
  - Cobalt: As shown on Figure E-15, cobalt was detected in 2015 at a concentration (174 µg/L) slightly above the baseline concentration of 227 µg/L. However, additional data are required to establish a statistically significant pattern showing an increase of these constituents in groundwater.
- 105: The manganese concentration detected at well 105 was below the baseline concentration. Figure E-16 in Appendix E shows that the manganese concentrations in the shallow bedrock groundwater nearly identical or increase only modestly between the upgradient well (128) and downgradient well (105).
- 116R: The concentrations of the constituents of concern at this well (antimony, arsenic, cadmium, chromium, cobalt, nickel, and cyanide) were all below the established baseline concentrations (Figures E-17 through E-23).
- 138: The concentrations of the constituents of concern at this well (carbon disulfide, antimony, arsenic, and cobalt) were all below the established baseline concentrations (Figures E-24 through E-27).
- PZ-06: The concentrations of the constituents of concern at this well (arsenic and manganese) were below the established baseline concentrations (Figures E-28 and E-29). In addition, the manganese concentration in groundwater is nearly identical to or less than the concentrations found in the two upgradient wells (128 and 133).

3.7 Conclusions

The results indicate the presence of 4-methylphenol, phenol, and metals in the downgradient overburden wells at concentrations that exceed the OU-7 groundwater cleanup standards. With the exception of manganese at well WP-11, the upgradient overburden wells do not contain constituents at concentrations above the OU-7 groundwater cleanup standards.

Carbon disulfide and metals are also present in the downgradient shallow bedrock wells at concentrations exceeding the OU-7 groundwater cleanup standards. With the exceptions of arsenic and cobalt at well 133 and manganese at well 128, the upgradient shallow bedrock wells do not contain constituents at concentrations above the OU-7 groundwater cleanup standards. Manganese concentrations appear to be similar in both upgradient and downgradient wells.

Control charts were developed for each downgradient well except well 024 to determine if concentrations are increasing in downgradient wells. A review of the control charts indicates that most constituents remain below their baseline concentrations, with the following exceptions:

- MW-09: 4-methylphenol, phenol, arsenic, chromium, cobalt, nickel, and vanadium
- WP-10: cobalt

These constituents were not significantly above their baseline concentrations. Additional data are required to establish a statistically significant pattern showing an increase in the groundwater concentrations.

4.0 OU-10 POST-CLOSURE GROUNDWATER MONITORING

This section presents the results of the eighth annual monitoring event completed in July 2015 as part of the post-closure maintenance of the VB 1-8 and the New Landfill, collectively referred to as OU-10. Figure 16 shows the layout of VB 1-8 and the New Landfill. The purpose of the post-closure groundwater monitoring of these units is to determine whether groundwater quality becomes further degraded, and if so, whether an unacceptable risk is posed by the change in water quality conditions.

Groundwater monitoring was conducted in accordance with the OU-7 GWMP approved by USEPA on February 29, 2012. As part of the 100% design submittal, the monitoring programs currently being conducted as part of OU-10 and the NTCRA Basin Closure (including the SBs and FABs) were combined with the requirements set forth in the OU-7 GWMP to create a single, comprehensive groundwater monitoring program. The OU-7 GWMP replaces the previously USEPA-approved monitoring plan for OU-10.

4.1 Monitoring Well Network

VB 1-8 and the New Landfill form a relatively contiguous management unit of over 20 acres along the northern portion of the Site west of the railroad tracks. A total of 19 wells have been identified as the monitoring network for the post-closure monitoring of these basins. Figures 16 and 17 show the locations of the monitoring wells, and Table 2 summarizes the construction details for the wells.

The current monitoring well network for VB 1-8 is listed in the table below:

Overburden	Shallow Bedrock
VB 1-8 Upgradient (ten Wells)	
GPW-02, GPW-03R, GPW-19, GPW-20	MW-7, MW-8, 118, 128, 130R, 133
VB 1-8 Downgradient (nine Wells)	
GPW-14, GPW-15R, MW-11, MW-12	MW-5, 119, 120R, 132, 135

The current monitoring well network for the New Landfill is listed in the table below:

Overburden	Shallow Bedrock
New Landfill Upgradient (three Wells)	
GPW-03R	128, 130R
New Landfill Downgradient (five Wells)	
GPW-19, GPW-20	MW-7, MW-8, 133

In addition to sampling the above noted wells, water level data only are collected from wells GPW-16R, GPW-17, GPW-18, GPW-21 and 134. Consistent with previous sampling events, well 133 is considered to be an upgradient well for VB 1-8 and a downgradient well for the New Landfill.

4.2 Water Level Measurements

In accordance with the OU-7 GWMP, synoptic water level measurements were obtained on July 7, 2015 prior to purging and sampling of the monitoring wells. Water levels were measured using an electronic water level meter and recorded to the nearest 0.01 feet in the bound field book dedicated for the sampling activities. Table 11 summarizes the elevation data obtained for each well.

The groundwater elevation contours for both the overburden and the shallow bedrock for July 2015 are shown on Figures 16 and 17, respectively. The groundwater contours for both the overburden and the shallow bedrock are similar to contour maps from previous monitoring events.

Piezometric gradients are generally west to northwest toward the Shenandoah River, perpendicular to the contour lines. Groundwater in the overburden is expected to flow parallel to the piezometric gradient (Figure 16). However, remedial investigation (RI) and OU-7 feasibility study (FS) results have demonstrated that groundwater within the bedrock aquifer flows parallel to a geologic strike at approximately S30ºW. This flow path represents an approximate 30 degree southward departure from the piezometric gradient.

4.3 Sample Analysis

The analyses performed on each OU-10 groundwater sample are listed below with the analytical methods.

- Dissolved metals by USEPA Method 6020A:
  - Antimony
  - Arsenic
  - Beryllium
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Nickel
  - Selenium
  - Thallium
  - Vanadium
  - Zinc
- Dissolved mercury by USEPA Method 7470A
- Cyanide (free) by USEPA Method 9014
- Target Compound List (TCL) VOCs by USEPA Method 8260B:
- TCL SVOCs by USEPA Method 8270D

4.4 Quality Assurance

As previously mentioned in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. The following QA/QC samples were collected in 2015.

- Eight equipment rinsate blanks distributed across all three monitoring units (OU-7/OU-10/Basins)
- Two field duplicate samples distributed across the monitoring units as follows:
  - OU-10: 1
  - OU-7/OU-10/Basins: 1
- Two matrix spike / matrix spike duplicate (MS/MSD) samples distributed across the units as follows:
  - OU-10: 1
  - OU-7/OU-10/Basins: 1
- One trip blank per cooler containing volatile organic compounds (VOC) samples.

Following laboratory analysis of the samples, ECCI performed data review, verification and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The results of the data validation associated with the OU-10 samples are summarized below and the data validation reports are provided as Appendix B.

All OU-10 data were considered usable with one exception: for group SDG AVX05, sample 2015AN-128 provided recoveries of all acid-fraction deuterated monitoring compounds (DMCs) below 10%. The results for all acid-fraction analytes reported as not-detected in the sample are flagged as unusable (R).

Data qualifiers have been added to some of the results. These qualifiers provide additional details regarding the data such as QC issues or interferences. Data qualified with a “J” indicate that, while the constituent was positively identified, the associated numerical value is an estimated concentration. Examples of data that may be qualified with this flag include values below the reporting limit (RL) but above the method detection limit (MDL), or where the associated QC samples are outside acceptable ranges.

With the exceptions noted below, the qualifiers added during the data validation process do not impact any of the decisions made using the data.

- For SDG AVX05, the results reported for free cyanide in all OU-10 samples (128 and 133)are flagged as estimated (J) due to non-compliant MS/MSD precision.
- For SDG AVX07:
  - Samples 2015AN-118, 2015AN-119, 2015AN-119D, 2015AN-120R, 2015AN-130R, 2015AN-GPW-02, 2015AN-MW-05, and 2015AN-MW-07 were associated with non-compliant continuing calibration verification (CCV) stability for chloromethane and 4-methyl-2-pentanone. The results

reported for these analytes in the samples are flagged as estimated (J) to signify the indication of low bias.

- The result reported for 2-chloronaphthalene in sample 2015AN-119 is flagged as estimated (J) due to non-compliant MS/MSD precision.

- Sample 2015AN-WP-11 provided non-compliant MS/MSD recoveries of mercury. The results reported for this analyte in all NTCRA Basin samples associated with the SDG (wells 114, PZ-06, and PZ-07) are flagged as estimated with the potential for low bias (J-).

The DQOs for the post-closure monitoring are to provide data of sufficient quality to evaluate changes in groundwater quality over time, if any, associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and the SW&SMP, definitive quantitation of the concentrations of COPCs in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQOs.

The monitoring plan calls for sampling 19 wells at OU-10. Each sample is analyzed for 115 constituents (13 metals, 38 VOCs, and 64 SVOCs) for a total of 2,188 constituent results. Thirteen results were rejected and therefore definitive quantitation for 99.4% of the constituents was achieved.

4.5 Results

Tables 12 and 13 present the validated analytical results for the VB 1-8 and the New Landfill wells, respectively, for the July and August 2015 sampling event and for previous events. The laboratory analytical data reports are contained in Appendix C.

As previously mentioned and in accordance with the OU-7 GWMP, the control chart approach was selected as the method for evaluating the data collected in each downgradient well. For the majority of monitoring wells, this baseline period was completed with the October 2009 sampling event. Certain monitoring wells (GPW-02, GPW-03R, GPW-15R, GPW-19, GPW-20, and 130/130R) were not sampled during one or more of the first four monitoring events because of dry conditions or because wells were abandoned due to on-site construction. Baseline concentrations for these monitoring wells were calculated when four sampling events had been completed. A baseline has now been established for each well in the monitoring network.

The monitoring data collected during the July and August 2015 sampling event were compared to the range of baseline concentrations (see Table 14). A control chart was generated if a parameter in a downgradient well was detected in exceedance of the range of baseline concentrations during the current or previous sampling event. Control charts were generated for acetone, methyl ethyl ketone, 2-hexanone, and xylenes at well GPW-14; xylenes and antimony at well 119; tetrachloroethylene (PCE) at well 132; and vinyl chloride at well MW-7. The control charts are included in Appendix F. Included on the control chart is the average concentration at the corresponding upgradient monitoring well. The July 2015 water quality data are compared to the baseline water quality data in qualitative terms below.

4.5.1 Viscose Basins 1-8

Upgradient Overburden

The data collected from the overburden monitoring wells GPW-02, GPW-03R, GPW-19, and GPW-20 are intended to represent water quality conditions upgradient of VB 1-8. As such, they are considered to represent background water quality concentrations. Control charts are not developed for upgradient wells.

- GPW-19 and GPW-20 have never been sampled because they have either been dry or contained insufficient water for sampling during every sampling event since February 2008.
- GPW-02
    - Four VOCs (acetone, methyl ethyl ketone, 2-hexanone, and xylenes) were detected in groundwater at upgradient well GPW-02 during the sampling event. None of the concentrations exceeded their respective Regional Screening Levels (RSLs), and all the values except methyl ethyl ketone were within the baseline range.
    - One SVOC (naphthalene) was detected in groundwater at upgradient well GPW-02 during the sampling event. The concentration was below the RSL and within the baseline range.
    - Five metals (beryllium, chromium, copper, nickel, and zinc) were detected at this location. All concentrations were below the RSL and within the baseline range.
- GPW-03R
    - No VOCs were detected at this location.
    - One SVOC (diethyl phthalate) was detected in groundwater at well GPW-03R. The concentration was below the RSL and within the baseline range.
    - Five metals (beryllium, copper, lead, nickel, and zinc) were detected in groundwater at this location. The detected concentrations of these metals were below their respective RSLs and within or below the range of baseline values established for these parameters.

Downgradient Overburden

Overburden monitoring wells GPW-14, GPW-15R, MW-11, and MW-12 are downgradient of VB 1-8. Results for these wells are provided below.

- GPW-14
    - Seven VOCs (methyl ethyl ketone, carbon disulfide, ethylbenzene, 2-hexanone, toluene, and xylenes) were detected at this well. The concentrations were all below their respective RSLs. However, four constituents (acetone, methyl ethyl ketone, 2-hexanone, and xylenes) exceeded their baseline ranges and control charts were generated for these constituents (Figures F-1 through F-4 in Appendix F).
        - Acetone and xylenes were only slightly above their baseline values; however, upgradient concentrations of these constituents have also increased.
        - The methyl ethyl ketone concentration at well GPW-14 was significantly above the baseline concentration in both the upgradient and downgradient wells.

        - The concentration of 2-hexanone at this location was only slightly above the baseline.
        - This is the first time these concentrations have been above their baseline. Continued monitoring is required to determine if an increasing trend is present.
    - Two SVOCs (diethyl phthalate and naphthalene) were detected at this well. The naphthalene concentration exceeds the RSL at this location but is below the baseline concentration; therefore, a control chart was not required.
    - Six metals (arsenic, cadmium, chromium, nickel, selenium and vanadium) were detected at this well; however, all concentrations were below the RSLs and baselines.
- GPW-15R
    - No VOCs or SVOCs were detected at this well.
    - Arsenic and zinc were the only metals detected at this location. Both metals were within the baseline range, and only arsenic exceeded the RSL.
- MW-11
    - Two VOCs (acetone and benzene) were detected in groundwater at well MW-11. Both constituents were below the RSL and within the baseline range.
    - No SVOCs were detected at this location.
    - Nine metals (arsenic, cadmium, chromium, lead, mercury, nickel, selenium, vanadium, and zinc) were detected in groundwater at well MW-11. All constituents were within the baseline range, and only arsenic exceeded the RSL.
- MW-12
    - Four VOCs (benzene, carbon disulfide, ethylbenzene, and xylenes) were detected in groundwater at well MW-12. The benzene concentration exceeded the RSLs, but was within the baseline range.
    - One SVOC (naphthalene) was detected at this well. The concentration exceeded the RSL, but was within the baseline range.
    - Six metals (arsenic, chromium, lead, nickel, selenium, and vanadium) were detected in groundwater at well MW-12. The arsenic concentration exceeded the RSL, but was within the baseline range.

The field parameter data are unremarkable, with one exception. The specific conductivity was elevated at wells GPW-14 (17.2 mS/cm), MW-11 (10.3 mS/cm), and MW-12 (14.1 mS/cm). The elevated specific conductivity in these wells is consistent with previous monitoring events.

Upgradient Shallow Bedrock

Upgradient groundwater quality in the shallow bedrock aquifer is represented by the data collected from wells MW-7, MW-8, 118, 128, 130R, and 133.

- MW-07
  - One VOC (vinyl chloride) was detected in groundwater at well MW-07. Vinyl chloride exceeds the RSL and the baseline range. A control chart is not required to evaluate upgradient groundwater conditions.
  - No SVOCs were detected at this location.
  - Three metals (arsenic, lead, and nickel) were detected in groundwater at well MW-07. Arsenic exceeds he RSL, but is within the baseline range.
- MW-08
  - No VOCs or SVOCs were detected in groundwater at well MW-08.
  - One metal (nickel) was detected; however, the concentration was below the RSL and within the baseline range.
- 118
  - No VOCs or metals were detected at this location.
  - One SVOC (naphthalene) was detected in groundwater at well 118. The naphthalene concentration was above the RSL but within the baseline range.
  - No metals were detected at this location.
- 128
  - No VOCs or SVOCs were detected in groundwater at this location.
  - Three metals (beryllium, copper, and nickel) were detected in groundwater at well 128. None of the constituents exceeded their respective RSLs and all were within baseline ranges.
  - As noted in Section 1.5 of this report, the results reported as non-detected for 13 SVOCs were rejected due to low laboratory QA/QC recoveries in the samples from this well and are unusable (results flagged with an R on Table 12).
- 130R
  - No VOCs or SVOCs were detected at this location.
  - One metal (beryllium) was detected in groundwater at well 130R. The concentration was below the RSL and within the baseline range.
- 133
  - One VOC (carbon disulfide) was detected in groundwater at well 133. The carbon disulfide concentration was below the RSL, but slightly above the baseline range.
  - No SVOCs were detected at this location.

- Five metals (arsenic, beryllium, chromium, nickel, and vanadium) were detected in groundwater at well 133. Only arsenic was detected at a concentration exceeding the RSL. The arsenic concentration was slightly above the baseline range as well.
- A control chart is not required to evaluate upgradient groundwater conditions.

Downgradient Shallow Bedrock

Downgradient water quality in the shallow bedrock is represented by the data collected from wells MW-05, 119, 120R, 132, and 135, which are downgradient of VB 1-8.

- MW-05
  - No VOCs or SVOCs were detected at this location.
  - Zinc was the only constituent detected in groundwater at this location. The concentration was below the RSL and within the baseline range.
- 119
  - Four VOCs (methyl ethyl ketone, ethylbenzene, toluene, and xylenes) were detected in groundwater at this location. None of the concentrations exceeded the RSLs; however, the xylenes concentration was above the baseline range. A control chart was generated for xylenes at this location (Figure F-5 in Appendix F). While the xylenes concentration was slightly above the baseline value; the upgradient concentrations also appear to be increasing slightly. This is the first exceedance of the baseline for this constituent and continued monitoring is required to determine if an increasing trend is present at this location.
  - One SVOC (naphthalene) was detected in groundwater at this location. The concentration exceeded the RSL but was within the baseline range for the constituent.
  - One metal (antimony) were detected in groundwater at this location. While the concentration was below the RSL, the baseline range for antimony was exceeded. Therefore, a control chart was generated for antimony at this location (Figure F-6 in Appendix F). This is the first exceedance of the baseline for antimony and continued monitoring is required to determine if an increasing trend is present at this location.
- 120R
  - No VOCs or SVOCs were detected at this location.
  - One metal (arsenic) was detected in groundwater at well 120R. The arsenic concentration was above the RSL but within the baseline range.
- 132
  - No VOCs or SVOCs were detected at this location.
  - While PCE was detected above the baseline value in groundwater at this well in 2014, the 2015 concentration remained below the baseline value. A control chart was generated for this constituent to show the decrease (Figure F-7 in Appendix F).

- Two metals (beryllium and vanadium) were detected in groundwater at this location. Both concentrations were below their RSLs and within baseline ranges.

4.5.2 New Landfill

Upgradient Overburden

GPW-03R is the only overburden monitoring well that is upgradient of the New Landfill.

- No VOCs were detected at this location.
- One SVOC (diethyl phthalate) and five metals (beryllium, copper, lead, nickel, and zinc) were detected in groundwater at this well. Detected concentrations were below their RSLs and within the range of baseline values for these parameters.

Downgradient Overburden

The overburden monitoring wells located downgradient of the New Landfill are GPW-19 and GPW-20. These monitoring wells have been consistently dry or have not contained sufficient water for sampling during each sampling event from March 2008 through July 2015. They will continue to be included in water level monitoring and will be sampled if sufficient water is present.

Upgradient Shallow Bedrock

Wells 128 and 130R monitor shallow bedrock upgradient of the New Landfill. As noted above, all of the constituents detected in these wells were below their respective RSLs and within baseline ranges.

Downgradient Shallow Bedrock

The water quality in the shallow bedrock downgradient of the New Landfill is represented by the data collected from wells MW-07, MW-08, and 133.

- MW-07
  - One VOC (vinyl chloride) was detected in groundwater at this location. The vinyl chloride concentration exceeds the RSL and the baseline range; therefore, a control chart was generated for vinyl chloride (Figure F-8 in Appendix F). The concentration of vinyl chloride at this location has dropped significantly since the observed increases in the previous two sampling events.
  - No SVOCs were detected at this location.
  - Three metals (arsenic, lead, and nickel) were detected in groundwater at well MW-07. The arsenic concentration exceeded the RSL, but is within the baseline range.
- MW-08
  - No VOCs or SVOCs were detected in groundwater at well MW-08.
  - One metal (nickel) was detected; however, the concentration was below the RSL and within the baseline range.

- 133
  - One VOC (carbon disulfide) was detected in groundwater at this location. The concentration was below the RSL, but above the baseline range for the constituent. A control chart was generated for carbon disulfide (Figure F-9 in Appendix F). Although the carbon disulfide concentration increased significantly in this well, the concentration remains well below the RSL.
  - No SVOCs were detected at this location.
  - Five metals (arsenic, beryllium, chromium, nickel, and vanadium) were detected in groundwater at well 133. Only arsenic was detected at a concentration exceeding the RSL and the baseline range. A control chart was generated for arsenic at this location (Figure F-10 in Appendix F). The arsenic concentration is expected to oscillate over time; concentrations will be monitored to determine if an increasing trend is present.

4.6 Conclusions

4.6.1 Viscose Basins 1-8 Overburden Groundwater

With a few exceptions, VOCs and SVOCs are not present in the overburden groundwater downgradient of VB 1-8. Acetone, benzene, methyl ethyl ketone, carbon disulfide, ethylbenzene, 2-hexanone, toluene, and xylenes were detected in one or more downgradient monitoring wells (predominantly GPW-14 and MW-12). These constituents have only been detected at relatively low concentrations and have not been observed in the upgradient wells. Therefore, VB 1-8 may be contributing trace levels of certain VOCs to groundwater in the overburden aquifer. Four of the VOCs (acetone, methyl ethyl ketone, 2-hexanone, and xylenes) were detected at concentrations exceeding the baseline ranges at well GPW-14. These constituents were not previously detected above the baseline ranges. One detection above the baseline range is not sufficient to determine if an increase in the concentrations has occurred. Future sampling events will provide the data required to determine if VB 1-8 is causing an increase in these constituents.

4.6.2 Viscose Basins 1-8 Shallow Bedrock Groundwater

With the exceptions of methyl ethyl ketone, ethylbenzene, toluene, and xylenes at well 119, VOCs and SVOCs are not present in the shallow bedrock groundwater downgradient of VB 1-8. The only constituents detected above their baseline concentrations in downgradient shallow bedrock groundwater were xylenes and antimony at well 119. While the xylenes concentration was slightly above the baseline value, the upgradient concentrations also appear to be increasing slightly. This is the first exceedance of the baseline concentrations for either of these constituents. Continued monitoring is required to determine if an increasing trend is present at this location. Although PCE had previously been detected above the baseline at well 132, the concentration was well below the baseline during the most recent sampling.

Antimony, arsenic, beryllium, nickel, vanadium, and zinc were detected at relatively low concentrations in one or more downgradient monitoring wells. The concentrations are not significantly above values detected in at least one upgradient well. In addition, the detected concentrations for all these metals were below or within the range of baseline values for these parameters. Therefore, VB 1-8 do not appear to be contributing metals to groundwater in the shallow bedrock. The detected concentrations could reflect naturally occurring levels of these metals.

4.6.3 New Landfill Overburden Groundwater

The two wells that are representative of upgradient overburden groundwater quality at the New Landfill have been sampled, but all downgradient overburden monitoring wells have been dry during each of the monitoring events. Based on the dry conditions at the downgradient monitoring wells, it appears that minimal overburden groundwater is present beneath and downgradient of the New Landfill.

4.6.4 New Landfill Shallow Bedrock Groundwater

Carbon disulfide (well 133) and vinyl chloride (well MW-07) were the only VOCs detected in the shallow bedrock monitoring wells downgradient of the New Landfill during the 2015 sampling event. Both detections exceeded their respective baseline ranges. Carbon disulfide has been intermittently detected at well 133, and vinyl chloride has been present in well MW-07 since 2013. There are insufficient data to determine if the concentrations of these constituents are increasing or stable. No SVOCs were detected in the shallow bedrock monitoring wells downgradient of the New Landfill during the 2015 sampling event. Therefore, it is concluded that the New Landfill is not contributing significant VOCs or SVOCs to groundwater in the shallow bedrock.

Concentrations of arsenic, beryllium, and nickel are elevated in the downgradient shallow bedrock wells compared to concentrations in the upgradient shallow bedrock wells, suggesting that these constituents may be derived from the New Landfill. However, with the exception of arsenic at well 133, the detected concentrations for these metals were below or within the range of baseline values in their respective wells. Additional monitoring data are required to determine if an increasing trend for arsenic is present at this location.

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5.0 NTCRA BASIN POST-CLOSURE GROUNDWATER MONITORING

This section presents the results of the results of the 15th annual groundwater sampling event implemented as part of the post-closure maintenance of the SB and FAB management units under the NTCRA Basin Closure. The 2015 annual event was the 13th annual event after establishing the baseline conditions. The SB and FAB units are shown on Figures 18 and 19. Post-closure groundwater monitoring of these units is conducted to determine whether groundwater quality becomes further degraded and, if so, whether an unacceptable risk is posed by the change in water quality conditions.

Groundwater monitoring was conducted in accordance with the OU-7 GWMP approved by USEPA on February 29, 2012. During development of the 100% design submittal for OU-7, the monitoring programs conducted as part of the OU-10 and NTCRA Basins closure (including the SBs and FABs) were combined with the requirements set forth in the OU-7 GWMP to create a single, comprehensive groundwater monitoring program. The OU-7 GWMP replaces the monitoring plan for NTCRA Basins previously approved by USEPA.

5.1 Monitoring Well Network

Figures 18 and 19 show the locations of the 10 overburden and 10 shallow bedrock monitoring wells that are monitored as part of the NTCRA Basin Post-Closure groundwater monitoring. Table 3 summarizes the construction details for these wells.

5.1.1 Fly Ash Basin Monitoring Well Network

FAB 1, 2, 3, and 6, and the former fly ash stockpile form a contiguous management unit of 47 acres. Twelve wells have been identified as the monitoring network for the post-closure monitoring of these closed units.

Overburden	Shallow Bedrock
Upgradient (four Wells)	
008, 029	108, 129
Downgradient (eight Wells)	
012, 013, 014R, B-48A	110, 112, 113, 114

5.1.1 Sulfate Basin Monitoring Well Network

SB 1, 3 and 4 form another contiguous management unit of 50 acres along the Shenandoah River. The sludge formerly contained in SB 5 was removed and placed in SB 4 and therefore no longer constitutes a potential source of constituents to groundwater. SB 2 has been cleaned out and closed and also no longer constitutes a potential source of constituents to groundwater. Fourteen wells have been identified as the monitoring network for the post-closure monitoring of the closed basins.

Overburden	Shallow Bedrock
Upgradient (eight Wells)	
MW-12, 012, 013, 014R	112, 113, 114, 132
Downgradient (six Wells)	
022, 023, 025R	PZ-03, PZ-06, PZ-07

5.1.1 Fly Ash Basin Cover System Drains

The cover system drain sumps were monitored as described in the OU-7 GWMP. The fly ash basin cover system drain sumps consist of the four sumps listed below. The locations of the sumps are shown on Figures 18 and 19.

- One sump is adjacent to FAB 2 and drains both FAB 1 and 2 (FAB-1-2);
- One sump is adjacent to FAB 3 (FAB-3-1); and
- Two sumps are adjacent to FAB 6 (FAB-6-North and FAB-6-South).

Each sump has a valved outlet that has remained closed. FMC has monitored the water levels within the sumps since the closure of the FABs was completed in February 2002. No water was present in the sumps until March 2003. In March 2003, the water level in the two sumps adjacent to FAB 6 overflowed the top of the sump at an estimated rate of 1 to 2 gallons per minute in each sump. In July 2003, FMC extended the elevation of the sumps in FAB 6 to prevent the sumps from overflowing. Although sumps FAB 1-2 and FAB 3-1 filled with water, the water did not overflow.

5.1.2 Sulfate Basin Cover System Drains

The cover system drain sumps were monitored as described in the OU-7 GWMP. The SB cover system drain sumps that were included in the monitoring network during the July 2015 sampling event consist of the four original sumps and the three additional sumps listed below. The locations of the sumps are shown on Figures 18 and 19.

- Four sumps are adjacent to SB 1 (SB-1-1, SB-1-2, SB-1-3, and SB-1-4);
- One sump is adjacent to SB 3 (SB-3-1); and
- Two sumps are adjacent to SB 4 (SB-4-1 and SB-4-2).

Sump SB 3-1 was installed in June 2010 and was sampled for the first time in September 2010. Sump SB-1-1 was installed after the September 2010 sump sampling event. Sump SB-1-2 was installed during May 2011, and sumps SB-1-3 and SB-1-4 were installed in August 2011. These sumps were sampled for the first time in June 2012. All sumps produced sufficient amounts of water for sampling during the 2015 sampling event.

5.2 Water Level Measurements

In accordance with the OU-7 GWMP, synoptic water level measurements were obtained before the monitoring wells were purged and sampled. Water levels were measured using an electronic water level meter and recorded to the nearest 0.01 foot in the bound field book dedicated to the sampling activities. Table 15 summarizes the elevation data obtained for each well on July 7, 2015.

The groundwater elevation (piezometric head) contours for both the overburden and the shallow bedrock for July 7, 2015, are shown on Figures 18 and 19, respectively. Piezometric gradients are toward the river perpendicular to the contour lines. Groundwater in the overburden is expected to flow parallel to the piezometric gradient. However, as previously mentioned, RI and OU-7 FS results have demonstrated that groundwater within the bedrock aquifer flows parallel to geologic strike at approximately S30ºW. This flow path represents an approximate 30 degree southward departure from the piezometric gradient.

5.3 Sample Analysis

The analyses performed on each groundwater and sump sample are listed below with the analytical methods.

- Dissolved metals by USEPA Method 6020A:
  - Arsenic
  - Beryllium
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Nickel
  - Selenium
  - Zinc
- Dissolved mercury by USEPA Method 7470A
- Cations USEPA Method 300.0:
  - Calcium
  - Magnesium
  - Sodium
- Anions by USEPA Method 300.0:
  - Chloride
  - Sulfate

5.4 Quality Assurance

As mentioned in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. The following QA/QC samples were collected in 2015.

- Eight equipment rinsate blanks distributed across all three monitoring units (OU-7/OU-10/Basins)
- To field duplicate samples distributed across the monitoring units as follows:

  - Basins: 1
  - OU-7/OU-10/Basins: 1
- Two matrix spike / matrix spike duplicate (MS/MSD) samples distributed across the units as follows:
  - Basins: 1
  - OU-7/OU-10/Basins: 1
- One trip blank per cooler containing volatile organic compounds (VOC) samples.

Following laboratory analysis of the samples, ECCI performed data review, verification and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The results of the data validation associated with the NTRCRA Basin samples are summarized below and the data validation reports are provided as Appendix B.

All NTCRA Basin data were considered usable. Data qualifiers have been added to some of the results. These qualifiers provide additional details regarding the data such as QC issues or interferences. Data qualified with a “J” indicate that, while the constituent was positively identified, the associated numerical value is an estimated concentration. Examples of data that may be qualified with this flag include values below the reporting limit (RL) but above the method detection limit (MDL), or where the associated QC samples are outside acceptable ranges.

With the exceptions noted below, the qualifiers added during the data validation process do not impact any of the decisions made using the data.

- For SDG AVX11:
  - Sulfate was out of specification. The results reported for this analyte in all NTCRA Basin samples associated with the SDG (wells 014R, 029, 129, 132, and MW-12) are flagged as estimated (J).
  - Sample 2015AN-132 provided inductively coupled plasma serial dilution values for calcium, iron, and magnesium differing by 15%, 15%, and 14%. The results reported for these analytes in all NTCRA Basin samples associated with the SDG (wells 014R, 029, 129, 132, and MW-12) are flagged as estimated (J) to signify the indication of high bias for calcium and magnesium and high bias for iron.
- For SDG AVX16:
  - Sample 2015AN-WP-11 provided non-compliant MS/MSD recoveries of mercury. The result reported for this analyte in the associated NTCRA Basin sample MW-09 is flagged as estimated with the potential for low bias (J-).
- For SDG AVX18, sample 2015AN-SB3-1 provided non-compliant MS/MSD recoveries of mercury. The results reported for this analyte in all samples associated with the SDG (wells and sumps 012, 022, 023, 112, 601, PZ-03, FAB1-2, FAB-3-1, FAB6-North, FAB6-South, SB1-1, SB1-2, SB1-3, SB1-4, SB3-1, SB3-1 duplicate, SB-4-1, and SB4-2) are flagged as estimated with the potential for low bias (J-).

The DQOs for the post-closure monitoring are to provide data of sufficient quality to evaluate any changes in groundwater quality over time associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and in the SW&SMP, definitive quantitation of the concentrations of COPCs in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQO.

The monitoring plan calls for sampling 32 wells and sumps at the NTCRA Basins. Each of the samples is analyzed for 15 constituents (10 metals, three cations, and two anions) for a total of 480 constituent results. Since no samples were rejected, definitive quantitation for 100% of the constituents was achieved.

5.5 Results

The validated analytical results for the FAB and SB wells and sumps for the 2015 sampling event and the field parameter data are presented on Tables 16 and 17, respectively. The laboratory validation report is presented in Appendix B, and the laboratory reports can be found in Appendix C. Historical analytical results are included on Table D-3 in Appendix D. Consistent with past sampling events, arsenic was the only constituent detected in groundwater at this unit at concentrations exceeding the RSL (Table 16).

As previously mentioned and in accordance with the OU-7 GWMP, the control chart approach has been selected as the method to evaluate the constituent data collected in each downgradient well. The range of baseline concentrations for each well was established from the initial four semi-annual sampling events in 2001 and 2002. The monitoring data collected during the 2015 event were compared to the range of baseline concentrations (see Tables 18 and 19). A control chart was generated if a constituent was detected in a downgradient sample at a concentration above the range of baseline concentrations. Included on the control chart is the average concentration at the corresponding upgradient monitoring well. Control charts are included as Appendix G. The 2015 water quality is compared to the baseline water quality in qualitative terms below.

5.5.1 Fly Ash Management Unit

Upgradient Overburden

The data collected from the overburden monitoring wells 008 and 029 represent water quality conditions upgradient of the fly ash unit. As such, they can be considered to represent upgradient concentrations for metals. Consistent with previous sampling results, the metals data for wells 008 and 029 were either non-detect or below the baseline range. The arsenic concentration detected in well 008 exceeds the RSL. Calcium, magnesium, and chloride were detected in groundwater at wells 008 and 029 at concentrations exceeding their respective baseline concentrations. Control charts were not generated because they are not required to evaluate upgradient groundwater conditions.

Downgradient Overburden

Wells 012, 013, 014R and B-48A are the four overburden monitoring wells downgradient of the fly ash units. With one exception, metals concentrations in groundwater at wells 012,013, 014R and B-48A were either non-detect or below the baseline range. Consistent with past results, arsenic was detected in well 014R at a concentration (692 µg/L) exceeding its baseline range of 46 µg/L to 66 µg/L. A control chart for arsenic in well 014R is presented in Appendix G (Figure G-1). The control chart shows that the arsenic concentration in groundwater at well 014R has remained relatively stable since 2008.

Calcium, magnesium, sodium, chloride, and sulfate were detected in one or more downgradient wells at concentrations exceeding their respective baseline concentrations. All the concentrations are similar to those detected in 2014. For example, the 2015 sodium concentration at well 014 R (787 milligrams per liter [mg/L]) is more than four times higher than the baseline level but is nearly identical to the concentration detected in 2014 (750 mg/L) and only slightly above the 2013 concentration (630 mg/L). The sulfate concentration in groundwater at well 014R in 2015 (2,540 mg/L) is nearly twice the baseline concentration but is similar to the concentration measured in 2013 and 2014 (2,710 mg/L and 2,410 mg/L, respectively).

Upgradient Shallow Bedrock

Upgradient shallow bedrock groundwater quality is represented by the data collected from wells 108 and 129. The metals concentrations in groundwater at wells 108 and 129 were either non-detect or below the baseline range.

The chloride concentration at well 129 (67.8 mg/L) is approximately twice the baseline range; however, the concentration is similar to the value measured in 2013 (75.8 mg/L) and 2014 (66.9 mg/L). Calcium and magnesium were also detected at values slightly above their baseline ranges, but not significantly above historical levels. The remaining cation and anion were reported at concentrations below baseline and are comparable to historical levels.

Downgradient Shallow Bedrock

Shallow bedrock wells 110, 112, 113, and 114 are downgradient of the FABs. With the exception of nickel at well 114, the metals concentrations at these wells were either non-detect or below the baseline range. Nickel was detected in well 114 at a concentration of 82.6 µg/L. Figure G-2 in Appendix G presents a control chart for nickel. The control chart shows a potential increasing trend for nickel concentrations at this well; however, the concentrations remain well below the RSL of 390 µg/L .

Historically, selenium has also been detected at well 114 at concentrations exceeding the baseline range; however, the selenium concentration was within the baseline range in 2013 and was not detected in 2014 or 2015. Therefore, a control chart is not presented for this constituent.

Several anions and cations were detected in groundwater at wells 112, 113, and 114 at concentrations exceeding their respective baseline concentrations. With the exception of sulfate at wells 112 and 114, the detected concentrations were only slightly above the baseline concentrations. There are no RSLs for these constituents, and control charts were not generated.

5.5.2 Sulfate Basin Management Unit

Upgradient Overburden

Overburden monitoring wells MW-12, 012, 013, and 014R collectively represent water quality conditions upgradient of the SBs. During the 2015 sampling event, arsenic was detected in groundwater wells MW-12 and 014R at concentrations exceeding the baseline values. Wells 012 and 013 did not contain detected concentrations of metals above respective baseline ranges during 2014. A control chart was not generated because one is not required to evaluate upgradient groundwater conditions.

Sodium, chloride, and sulfate were all detected in groundwater at well MW-12 at concentrations significantly higher than the baseline results. Calcium, magnesium, and sulfate were also detected in groundwater at well 013, and magnesium, sodium, chloride, and sulfate were detected at well 014R. The concentrations at both wells exceeded their baseline concentrations. These results are consistent with past findings.

Downgradient Overburden

Wells 022, 023, and 025 represent the overburden groundwater quality downgradient of the SBs. The metals concentrations in groundwater at wells 022, 023 and 025 were either non-detect or below the baseline range. Arsenic was detected at a concentration (2.3 J µg/L) within the range of baseline values at well 023. The arsenic concentration at this well has historically exceeded the baseline range; however, the concentrations were below the baseline in 2014 and 2015. Figure G-3 in Appendix G presents the control chart for arsenic at well 023. The chart shows significantly higher upgradient arsenic concentrations, suggesting that the SBs are not a source of arsenic. In addition, the downgradient arsenic concentration has decreased slightly over the monitoring period. Consistent with past results, slight exceedances of the baseline concentrations for calcium and magnesium at well 023 were also observed.

Upgradient Shallow Bedrock

Concentrations at wells 112, 113, 114, and 132 represent groundwater conditions in the shallow bedrock upgradient of the SBs. With the exception of nickel at well 114, the metals data for wells 112, 113, 114 and 132 were either non-detect or below the baseline range. Consistent with past results, several cations and anions were also detected at concentrations exceeding their baseline ranges. The largest exceedances were measured for sulfate at wells 112 and 114. The sulfate concentration at well 112 (928 mg/L) was consistent with the concentration measured in 2014 (932 mg/L). The sulfate concentration at well 114 (1,420 mg/L) is consistent with values measured in 2014 (1,390 mg/L) and 2013 (1,420 mg/L).

Downgradient Shallow Bedrock

The downgradient water quality in the shallow bedrock is represented by the data collected from wells PZ-03, PZ-06, and PZ-07. The metals data for wells PZ-03, PZ-06, and PZ-07 were either non-detect or below the baseline range. While arsenic was detected at well PZ-06 at concentrations above the baseline during the four previous sampling events (2011 through 2014), the concentration has been dropping and is now within the baseline range. Magnesium and chloride at well PZ-03 and chloride at well PZ-07 were detected at concentrations slightly above their baseline range.

5.5.3 Fly Ash Basin Cover System Drain Sumps

The validated 2015 data for the samples collected from the four FAB sumps (FAB-1-2, FAB-3-1, FAB-6-North, FAB-6-South) are presented in Table 17. Historical results are presented in Appendix D. The analytical results were compared to the more stringent freshwater standards for either aquatic life or human health contained in the Virginia surface water quality standards (VAC[4] 25-260-140). The appropriate screening criteria for each constituent are listed on Table 16. Key findings are as follows:

- Arsenic was detected in one (FAB-1-2) of the four sumps at concentrations exceeding the screening criteria of 10 µg/L. The concentration of arsenic at this location increased by two orders of magnitude compared to the 2014 result. The 2015 concentration is similar to concentrations measured at this location between 2006 and 2008. The arsenic concentrations in the remaining sumps decreased slightly compared to concentrations measured in 2014.
- The concentrations of nickel at each sump exceeded the screening criteria of 20 µg/L, with concentrations ranging from 25.3 to 48.9 µg/L. This is consistent with the results from 2014 and remains below this historically high levels reported in 2011.
- The concentration of zinc at sump FAB-3-1 (221 µg/L) exceeded the RSL of 120 µg/L. This represents a slight increase from the concentration detected in 2014 (160 µg/L). The zinc concentration has fluctuated significantly during the monitoring period ranging from 9.2 (2012) to 2,700 µg/L (2003).
- The concentrations of sulfate in the four sumps (ranging from 441 to 996 mg/L) exceed the screening criteria of 250 mg/L. The concentrations have remained relatively stable or have decreased slightly since monitoring began in 2003.
- Consistent with historical results, beryllium, cadmium, and mercury were not detected in any of the sumps.

5.5.4 Sulfate Basin Cover System Drain Sumps

The validated 2015 data for samples collected from the seven FAB sumps (SB-1-1, SB-1-2, SB-1-3, SB-1-4, SB-3-1, SB-4-1 and SB-4-2) are presented on Table 17. Historical results are presented in Appendix D. The analytical results were compared to the more stringent freshwater standards for either aquatic life or human health contained in the Virginia surface water quality standards (VAC 25-260-140). The appropriate screening criteria for each constituent are also presented on Table 16. Key findings from the SB sump sampling in 2015 are as follows:

- The concentration of arsenic at sumps SB-1-1 (43 µg/L), SB-3-1 (12.8 µg/L), and SB-4-2(SE) (53.2 µg/L) exceeded the screening criteria of 10 µg/L. The results are consistent with the values detected in 2013 and 2014 at these sumps. Prior to 2013, the arsenic concentrations at these locations were below the screening criteria.
- The concentration of copper at sump SB-1-4 (10.4 µg/L) slightly exceeds the screening criteria. This represents a slight increase from the 2014 result (3.3 µg/L).
- The concentrations of nickel at sumps SB-1-3 (20.8 µg/L) and SB-1-4 (2 µg/L) exceed the screening criteria of 20 µg/L. The concentration at SB-1-3 has increased since 2013; however, the concentration at SB-1-4 is consistent with historical results.
- Sulfate concentrations exceed the screening criteria of 250 mg/L in four of the seven sumps (SB-1-3, SB-1-4, SB-4-1[NW], and SB-4-2[SE]), with

[4] VAC – Virginia Administrative Code

concentrations ranging from 302 mg/L to 1,330 J mg/L. The sulfate concentrations in the SB sumps have generally decreased since monitoring began in 2012 (sulfate concentrations exceeded the screening criteria in six sumps in 2012).

- Consistent with historical results, beryllium, cadmium, and mercury were not detected in any of the sumps.

5.6 Conclusions

5.6.1 Fly Ash Management Unit

Monitoring of metals in the overburden wells indicates a potential increasing trend of arsenic concentrations in well 014R downgradient of FAB 3 relative to the concentration in the upgradient well. However, the concentrations of arsenic have remained relatively stable since 2008. The potential increasing trend for arsenic at well 014R will be tracked in subsequent monitoring events. There have also been notable increases in sodium and sulfate at well 014R since the inception of the monitoring program in 2001.

Monitoring of metals in the shallow bedrock wells both upgradient and downgradient of the FAB units did not indicate any increasing trends in metal concentrations, with the possible exception of nickel in well 114. The control chart for this constituent shows a potential increasing trend for nickel concentrations at this well, although the concentrations remain an order of magnitude below the RSL. Sulfate concentrations in downgradient wells 112 and 114 were elevated relative to the upgradient wells and concentrations measured during baseline data collection.

5.6.2 Sulfate Basin Management Unit

Results of metals monitoring in the overburden wells both upgradient and downgradient of the SB units did not indicate any increasing trends in metal concentrations. The major ion concentrations are also relatively stable.

Results of metals monitoring in the shallow bedrock wells both upgradient and downgradient of the SB units did not indicate any increasing trends in metal concentrations.

5.6.3 Fly Ash Basin Cover System Drain Sumps

The water quality data collected from the sumps indicate that arsenic, nickel, zinc, and sulfate were present during the 2015 sampling event at concentrations exceeding Virginia’s surface water quality standards (9 VAC 25-260-140). With the exception of arsenic at sump FAB-1-2, the concentrations of these constituents have decreased or remained stable over time. Additional data are required to determine if the increase at FAB-1-2 is an anomaly or represents a trend.

5.6.4 Sulfate Basin Cover System Drain Sumps

The 2015 event represents the 10^{th} sampling event for sumps SB 4-1 and SB 4-2, the sixth sampling event for SB 3-1, and the fourth sampling event for sumps SB-1-1, SB-1-2, SB-1-3, and SB-1-4. The water quality data indicate that arsenic, nickel, and sulfate were present at concentrations exceeding Virginia’s surface water quality standards (9 VAC 25-260-140). The concentrations of COPCs in these sumps has decreased or remained stable over the monitoring period.

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6.0 OU-7 SURFACE WATER AND SEDIMENT MONITORING

This section of the report summarizes activities conducted in 2015 as part of the implementation of the SW&SMP for OU-7 of the Site (ERM 2014). The SW&SMP was prepared and implemented in accordance with Section 11.2.8 of the Record of Decision issued by the USEPA on January 13, 2010 (USEPA 2010) to monitor the effectiveness of the OU-7 remedy. As stated in Section 1.3 of the SW&SMP, the purpose of the SW&SMP with respect to surface water and sediment monitoring is to:

- Evaluate surface water quality and sediment data from the Shenandoah River to determine whether there are decreasing trends in the concentration of constituents found in the area where the groundwater contamination plume from VB 9-11 is entering the river; and
- Evaluate surface water and sediment data to determine whether the remediation of the groundwater plume has a beneficial effect on sediment and surface water quality in the vicinity of the plume discharge.

An additional purpose of monitoring is to evaluate whether groundwater extraction is reducing or eliminating the discharge of contaminated groundwater into the river. This section presents the results of the July 2015 fourth annual river surface water and sediment sampling event, which was conducted in accordance with Section 2.0 of the SW&SMP. The triennial aquatic biota sampling described in Section 3.0 of the SW&SMP was also conducted in 2015. The results of that sampling are presented in Section 7 of this report. Historical river sampling results are included in Appendix H.

6.1 Sample Collection

Surface water and sediment samples were collected on July 11 and 12, 2015, in accordance with the procedures described in the SW&SMP and as described below.

6.1.1 Sample Locations

Surface water and sediment samples were collected at eight locations (numbered SED/SW-1 through SED/SW-8) in the river (Figure 20). With the exception of location SED/SW-8, the sample locations approximately replicated the locations sampled in 2001 (Exponent 2001). The 2001 samples were collected from a seepage area that was observed to contain discolored sediment with a sulfide odor (Appendix M, Figure M-1). Sample location SED/SW-8 was added to the sampling plan at USEPA's request. The July 2015 event was the first time the location was sampled. The sampling locations represented surface water and sediment quality upstream of the Site (Location SED/SE-8), upstream of the VB 9-11 plume (Locations 6 and 7), adjacent to the plume (Locations 3, 4, and 5), and downstream of the plume (Locations 1 and 2).

Surface water samples were collected before sediment samples. The locations of the sampling stations were identified and marked by Marsh & Legge Land Surveyors based on the past surveyed locations. Marsh & Legge marked the river bank at each location and provided an off-set distance for collecting the surface water samples. Permanent markers were placed on the bank marking the location of each sample for future reference. The coordinates for the locations as provided by Marsh & Legge are presented below:

Offset Description and Distance	Northing	Easting
SW-01 35' O/S	7019406.637	11563405.654
SW-02 70' O/S	7019281.052	11563494.633
SW-03 50' O/S	7019051.766	11563678.012
SW-04 40' O/S	7018973.457	11563741.140
SW-05 50' O/S	7018939.171	11563777.939
SW-06 50' O/S	7018652.006	11563958.070
SW-07 50' O/S	7018582.984	11564015.187
SW-08 75' O/S	7016074.103	11565471.872

6.1.2 Equipment Decontamination

Sampling equipment was decontaminated following the procedures described in Section 2.3.2 of the SW&SMP. All sampling equipment used at multiple locations was decontaminated in the field prior to beginning sampling activities, after use at each sample location, and prior to leaving the Site. Any equipment that could not be decontaminated or was designated for one-time use (e.g., nitrile gloves) was properly packaged and disposed of as nonhazardous solid waste.

6.1.3 Measurement of Field Parameters

Field measurements in the Shenandoah River were collected by immersing the instrument probes into a container filled with water from each sampling location.

6.1.4 River Water Sample Collection Procedures

Samples were collected in accordance with the procedures described in Section 2.3.4 of the SW&SMP while standing in the river. The river was between 1 and 1-1/2 feet deep at each location during the sampling event. Samples were obtained from one-half the stream depth at mid-channel using new, clean laboratory-supplied containers, which were inverted and lowered into the channel. For laboratory-supplied containers that held preservatives, a separate clean container was used to collect the sample, and the contents were then transferred into the pre-preserved laboratory-supplied container.

Samples collected for dissolved metals were collected in an unpreserved bottle, then pumped through a 0.45-micron in-line filter and transferred to the bottles containing the appropriate preservative. The initial 200 milliliters of the filtered sample was discarded.

6.1.5 River Sediment Sample Collection Procedures

Sediment samples were collected from the top six inches. In order to obtain appropriate sample volumes, multiple sub-samples were collected at the sampling location and homogenized into a representative composite sample using a stainless steel spoon and mixing bowl. Samples to be analyzed for VOCs were drawn from the first aliquot, prior to homogenization. The samples were placed directly into the appropriate laboratory-supplied containers. The sediment samples were collocated with surface water sampling locations.

6.2 Sample Analysis

The samples were submitted to Lancaster for analysis using the analytical methods listed below in accordance with Section 2.5 of the SW&SMP.

- Dissolved metals (surface water) and total metals (sediment) by USEPA Method 6020:
  - Aluminum
  - Antimony
  - Arsenic
  - Cadmium
  - Chromium
  - Cobalt
  - Iron
  - Lead
  - Manganese
  - Nickel
  - Vanadium
  - Zinc
- Dissolved mercury (surface water) by USEPA Method 7470A
- Total mercury (sediment) by USEPA Method 7471B
- Free cyanide by USEPA Method 9014 (surface water)
- Total cyanide by USEPA Method 9012 (sediment)
- VOCs by USEPA Method 8260B:
  - Acetone
  - Carbon disulfide
  - Chlorobenzene
- SVOCs by USEPA Method 8270D:
  - 2-Methylphenol
  - 4-Methylphenol
  - Bis(2-ethylhexyl)phthalate
  - Naphthalene
  - Pentachlorophenol
  - Phenol

- Grain size by Method ASTM[5] D 422, percent solids by Method 2540, and TOC by Method USEPA Lloyd Kahn (sediment samples only).

6.3 Quality Assurance

As discussed in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. The following QA/QC samples associated with the surface water and sediment sampling were collected in 2015.

- One equipment rinsate blank was collected with the sediment samples.
- One sediment and one surface water field duplicate samples were collected.
- One sediment and one surface water matrix spike / matrix spike duplicate (MS/MSD) samples were collected.
- One trip blank per cooler containing volatile organic compounds (VOC) samples.

Following laboratory analysis of the samples, ECCI performed data review, verification and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The results of the data validation are summarized in Section 1.5, and the data validation reports are provided as Appendix B.

All data were considered usable with one exception: for SDG AVX04, the result reported as not detected for chlorobenzene in sample 2015AN-SED-02 is flagged as unusable (R) due to non-compliant Internal Standards (IS) response.

Data qualifiers have been added to some of the results. These qualifiers provide additional details regarding the data such as QC issues or interferences. Data qualified with a “J” indicate that, while the constituent was positively identified, the associated numerical value is an estimated concentration. Examples of data that may be qualified with this flag include values below the reporting limit (RL) but above the method detection limit (MDL), or where the associated QC samples are outside acceptable ranges.

With the exceptions noted below, the qualifiers added during the data validation process do not impact any of the decisions made using the data.

- For SDG AVX04:
    - The result reported for pentachlorophenol in sample 2015AN-SW-04 is flagged as estimated (J) due to non-compliant MS/MSD precision.
    - Mercury was out of specification in sample 2015AN-SED-04. The results reported for this analyte in sediment samples are flagged as estimated (J). These results are considered usable when the precision factor is taken into account. Doing so will impact the decision for samples 2015AN-SED-01 and 2015AN-SED-02 since one is below and one above the standard. For samples 2015AN-03 and 2015AN-04, no impact is indicated since both are below and above the standard, respectively

[5] ASTM – American Society for Testing and Materials

- The positive results for acetone and carbon disulfide in sample 2015AN-SED-02 are flagged as estimated (J) due to non-compliant IS response.
- The result reported as not-detected for chlorobenzene in sample 2015AN-SED-02 is flagged as unusable (R) due to non-compliant IS response.
- Sample 2015AN-SED-04 provided MS/MSD recoveries of antimony, arsenic, and mercury below the lower limit. The positive results reported for this analyte in all sediment samples are flagged as estimated with the potential for low bias (J-). These results are considered usable when the bias factor is taken into account. For antimony and arsenic, doing so will have no impact on the decision since the adjusted values are below the standard. For mercury, doing so will impact the decision for samples 2015AN-SED-01, 2015AN-SED-02, and 2015AN-SED-03 since the unadjusted values are below and adjusted values above the standard. For mercury, doing so will have no impact on the decision for samples 2015AN-SED-04 and 2015AN-SED-04D since the unadjusted values are above the standard.
- Sample 2015AN-SED-04 provided inductively coupled plasma serial dilution values for cobalt and lead differing by 12% and 14%. The results reported for these analytes in all sediment samples are flagged as estimated (J) to signify the indication of low and high bias, respectively.

The DQOs for the post-closure monitoring are to provide data of sufficient quality to evaluate any changes in groundwater quality over time associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and the SW&SMP, definitive quantitation of the concentrations of COPCs in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQO.

The surface water and sediment monitoring plan calls for analysis of eight surface water samples for a total of 24 constituents (13 metals, three VOCs, six SVOCs, free cyanide, and total cyanide) and eight sediment samples for a total of 26 constituents (13 metals, three VOCs, six SVOCs, free cyanide, total cyanide, TOC, and grain size). This totals 400 results. With one result (the non-detect result for chlorobenzene at SED-02) rejected, definitive quantitation for 99.75% of the constituents was achieved (which exceeds the DQO of 90%).

6.4 Results

6.4.1 River Flow

River flow conditions were determined based on information obtained from the United States Geological Survey (USGS) gauging station for the Shenandoah River at Front Royal, Virginia (USGS Station 01631000). The average flow of the river during the sampling event, July 11 to July 12, 2015, was 1,007 cubic feet per second (cfs). The minimum and maximum discharge of the River on those dates was 891 cfs and 1,260 cfs, respectively. For comparison, flow ranged from a low of 250 cfs on September 25, 2015, to a high of 12,800 cfs on October 4, 2015. Based on 86 years of flow monitoring at this gauging station, low-flow conditions occur between mid-August and the end of October each year and typically average about 500 cfs.

6.4.2 River Sediment

The results of the river sediment samples are presented in Table 20. The sediment results were compared to the USEPA Region 3 Freshwater Sediment Screening Benchmarks (USEPA 2006). Historical sediment data are presented in Appendix H.

Consistent with past results, no SVOCs were detected above the screening criteria in any of the seven samples collected from historical sediment sampling locations. However, three SVOCs were detected at the new sample location (SED-08). The analytical results for specific VOCs and SVOCs in river sediment samples are listed below:

- Acetone was detected in sediment at all eight of the seven locations with concentrations ranging from 21 (SED-07) to 100 J (SED-02) micrograms per kilogram (µg/kg). These results are consistent with past events. There is no sediment criterion for acetone.
- Carbon disulfide was detected at all eight locations at concentrations exceeding the screening criteria. Detected concentrations ranged from 3 J µg/kg (SED-08) to 100 µg/kg (SED-04). The results are consistent with historical data. Groundwater extraction has not significantly impacted the carbon disulfide levels in sediment.
- Consistent with past results, chlorobenzene was not detected in any of the samples.
- 4-Methylphenol was detected at a concentration of 1,600 µg/kg at upstream location SED-08. Naphthalene and phenol were also detected at this location, but the concentrations did not exceed the screening criteria. Since this location is upstream of the Site, these constituents are not believed to be related to site activities. This location has not been sampled in the past.
- Relatively low concentrations of 4-methylphenol (SED-04) and naphthalene (SED-05, SED-06, SED-07, and SED-08) were also detected, but all concentrations were below the screening criteria. The concentration of 4-methylphenol at SED-04 was 30 J µg/kg. The concentration of naphthalene ranged from 10 J µg/kg (SED-06) to 17 J µg/kg (SED-08). These constituents have not historically been detected. The detections in 2015 are likely due a decrease in the detection limits for these constituents.
- As shown in Appendix H (Table H-1), the level of fine particles (clay and silt) observed in the sediment samples is similar or greater than those reported in previous sampling events.

The analytical results for metals and cyanide in the river sediment samples are as follows:

- Antimony, arsenic, cadmium, chromium, cobalt, lead, nickel, and zinc were reported as non-detect or at concentrations below the freshwater sediment screening benchmarks in all samples.
- Aluminum and vanadium were detected in all of the samples, but there are no freshwater sediment screening benchmarks for these constituents. The highest concentrations of these metals were found in upgradient samples SED-06 and SED-08. Increases in the concentration of these metals have been observed in upstream locations SED-06 and SED-07. Location SED-08 has not been

sampled prior to 2015. The concentrations of these metals have been relatively consistent at all other sampling locations. Therefore, their presence of these metals in sediment does not appear to be related to site activities.

- Iron was detected in upgradient sample SED-08 at a concentration (40,300 milligrams per kilogram [mg/kg]) exceeding the screening criteria. Iron was below the screening criteria in the remaining samples. Iron has been sporadically detected at several locations in the past with concentrations exceeding the benchmarks.
- Manganese was detected at three locations (SED-04, SED-06, and SED-08) at concentrations exceeding the screening criteria (501 mg/Kg, 791 mg/Kg, and 1,000 mg/Kg, respectively). However, the duplicate sample collected at location SED-04 (387 mg/Kg) did not exceed the criteria. Manganese has been sporadically detected at several locations in the past with concentrations exceeding the benchmarks.
- Mercury was detected at three locations (SED-04, SED-07, and SED-08) at concentrations (0.347 J- mg/Kg, 0.210 J- mg/Kg, and 0.302 J- mg/Kg, respectively) exceeding the freshwater screening benchmark values. Two of these locations are upgradient of the plume. Mercury exceeded the benchmarks at SED-03 (0.19 mg/Kg) and SED-04 (0.22 mg/Kg) in 2014, but has not historically been detected at concentrations exceeding the benchmark at other locations.
- Consistent with historic results, total cyanide was not detected in any of the samples.
- Metals occur naturally in river sediment. Therefore, the presence of metals, in particular iron and manganese, above the analytical RLs is expected. Metals such as arsenic and antimony present in the VB 9-11 groundwater plume were either non-detect or detected at concentrations below benchmark values.
- The concentrations of metals detected in sediments in 2015 are relatively consistent with results reported from 2013 and 2014.

6.4.3 River Water

The results of the river water samples are presented in Table 21. The surface water data collected during the July 2015 event were compared to the Virginia Department of Environmental Quality (VADEQ) Chronic Surface Water Criteria for freshwater and human health ~~Public Water Supply~~ (2017~~2~~). In addition, the data were compared to the USEPA Region III Biological Technical Assistance Group Freshwater Benchmarks. Historical water quality data are presented in Appendix H.

No VOCs or SVOCs were detected in river surface water samples. Concentrations of metals in river surface water samples were reported as non-detect or at concentrations below the surface water criteria at all sampling locations. This is consistent with historical results.

6.5 Conclusions

The key findings from the river water and sediment sampling event are summarized below.

6.5.1 River Sediment

- Consistent with past sampling events, carbon disulfide was detected in sediment samples near the OU-7 plume above the sediment criteria. The concentrations were similar to previous levels and groundwater extraction has not significantly impacted the concentrations in sediment..
- 4-methylphenol was detected above the sediment criterion at upstream location SED-08. The highest SVOC and metals concentrations in sediment were reported in the upstream sample SED-08.
- No other VOCs or SVOCs were detected at concentrations above the sediment criteria.
- With the exception of iron, manganese, and mercury, all metals were reported as non-detect or at concentrations below the freshwater sediment screening benchmarks. The concentrations of metals detected in sediments in 2015 are relatively consistent with results reported from 2013 and 2014.
- Consistent with historical results, total cyanide was not detected in any of the samples.

6.5.2 River Water

- No VOCs or SVOCs were detected in river surface water samples.
- Concentrations of metals in river surface water samples were reported as non-detect or at concentrations below the surface water criteria at all sampling locations. This is consistent with historical results.

7.0 OU-7 AQUATIC BIOTA SAMPLING

Parsons collected aquatic biota and sediment samples from six sampling locations from the South Fork Shenandoah River adjacent to the Site from September 14 through 18, 2015. This section describes the species collected at each location, the methods used to collect and analyze the aquatic biota and sediment samples, and the results of the analysis. Minor deviations from the methods described SW&SMP are also discussed.

7.1 Sample Locations

The aquatic biota and sediment sampling sites were designated BMI-1 through BMI-6 in accordance with the nomenclature used in the SW&SMP (Figure 21). In some cases, the river locations sampled differed slightly from those referenced in the SW&SMP because the target species were not present at the exact location referenced in the SW&SMP. The observed distribution of the target species was generally consistent with known habitat preferences for the species.

In most cases where sample locations were adjusted due to species distribution in the field, all samples were collected within 50 to 100 meters of the locations depicted in the SW&SMP. The largest sample location deviation in the field was at BMI-6, where the minnow tissue sample was taken approximately 200 meters downstream of the sample location referenced in the SW&SMP. This was the closest location to BMI-6 in which minnows were observed.

The coordinates for each sample site for the aquatic biota sampling are shown below.

Sample Location	Latitude	Longitude
BMI-1	38.936168	-78.219386
BMI-2	38.932384	-78.220625
BMI-3	38.930163	-78.220031
BMI-4	38.925897	-78.219531
BMI-5	38.921226	-78.216326
BMI-6	38.910973	-78.210440

7.2 Sample Collection Procedures

Each sample was assigned a unique sample tracking number using the basic format described in the SW&SMP. The sample identification number consisted of the Event Code-Location Code-Media Code-Species Code-Sample Number. All non-disposable sampling equipment was decontaminated using the procedures described in section 2.3.2 of the SW&SMP.

Aquatic biota sampling and analysis involved the collection of fish and benthic macroinvertebrates and collocated sediment samples. Parsons' aquatic biota sample collection procedures are described in Standard Operating Procedure 1 of the SW&SMP and are summarized below.

7.2.1 Fish

According to the SW&SMP, the target species for the fish collection included smallmouth bass (*Micropterus dolomieu*), redbreast sunfish (*Lepomis auritus*), common carp (*Cyprinus carpio*), and fathead minnow (*Pimephales promelas*). The SW&SMP specified collection of triplicate samples for each species at each site. The fish collected based on the species found in the river during the sampling event are described below.

- **Smallmouth bass.** Whole fish triplicate samples were captured at all six locations for smallmouth bass.
- **Redbreast sunfish.** Whole fish triplicate samples were captured at BMI-3, BMI-5, and BMI-6 for redbreast sunfish. Only whole fish replicate samples were captured at BMI-1, BMI-2, and BMI-4, with the exception of BMI-2 where one of the samples was a composite of two redbreast sunfish due to the small size of the fish captured.
- **Minnow.** No fathead minnows or species within the same genus (Pimephales) were found at any of the sampling locations. In lieu of collecting Pimephales species, comely shiner (Notropis amoenus) and common shiner (Luxilus cornutus) composite samples were collected in triplicate at all sites, except BMI-6. At BMI-6, only one composite sample of the comely shiner could be collected. Since the comely shiner and common shiner have similar life histories, occupy similar ecological niches, and are similar in size to the fathead minnow, the comely shiner and common shiner were retained for analysis as a substitute for the fathead minnow.
- **Carp.** No carp were captured at any of the sites. Carp are typically found in deeper pools, which were not present in the stretch of river adjacent to the Site. In lieu of collecting carp, fallfish (Semotilus corporalis) and northern hogsucker (Hypentelium nigricans) whole and composite samples were collected, except at BMI-3. At BMI-3, no fallfish or northern hogsucker were collected. Fallfish were retained for analysis, because fallfish and carp belong to the same family (Cyprinidae). Fallfish are also the largest native minnow in Virginia, averaging 15 to 30 centimeters in length, making it the most comparable in size to carp of all cyprinids collected during the sampling effort. Fallfish also have similar food habits to carp in that they eat insects and other invertebrates, fish, and detritus. Although the northern hogsucker (family Catostomidae) is not within the same family as carp, they were retained for analysis in lieu of carp and fallfish, because they are a bottom-feeding species, feeding primarily on benthic organisms, similar to carp. Note that USEPA in 1999 and ERM in 2012 also targeted, but failed to capture carp in the river.

The fish collections were completed in accordance with the protocol established in the SW&SMP. Seine nets were effective for capturing the shiners, northern hogsucker, fallfish, and redbreast sunfish, but hook and line was the most effective at capturing smallmouth bass, redbreast sunfish, and fallfish. Gill nets were not effective for collection, because the river's current was too swift to adequately anchor the gill nets with the materials on hand and because floating algae and detritus lodged in the netting. It is unlikely that the algae burdened nets would be effective even if a suitable anchor was present.

No visible anomalies were observed on any of the fish specimens. The protocol for processing the fish specimens included in Section 3.3.3 of the SW&SMP was followed.

Section 3.3.3 of the SW&SMP specified that the sex of each fish be identified to the extent practicable. However, specimens did not have dependable external secondary sex characteristics, because the specimens were collected outside of the spawning season. Therefore, in the absence of dissection, the determination of sex for each specimen was not practicable or possible.

7.2.2 Benthic Macroinvertebrates

The benthic macroinvertebrate collections were completed in accordance with the SW&SMP's protocol for collecting and processing benthic macroinvertebrate samples. Clams were collected by hand from each of the six sample locations on the river and were composited according to the protocol in the SW&SMP samples. The clams were not present in sufficient quantities to collect a complete sample at the exact sampling location specified in the SW&SMP. However, in most cases, clams were collected within an approximately 25- to 50-meter radius of the designated sampling sites.

Fingernail clams from the family Sphaeriidae were the target species, but only Asian clams (Corbicula fluminea) were observed at each sampling site. Corbicula clams are similar to Sphaeriidae clams in terms of their size, habitat, and feeding. Therefore, Corbicula clams were retained for analysis as a substitute for Sphaeriidae clams. Collecting samples of the clams in triplicate or replicate would have been very labor intensive and not feasible due to the small size of the individual clams and the lack of clams in some sample locations. Therefore, a sufficient number of clams were collected from each sampling site for one composite sample. Table 22 summarizes the numbers of each fish species and Corbicula clams collected at each BMI sampling location and presents the observations of each sample collected including species, length, weight, and external pathology.

7.3 Sample Analysis

The samples were submitted to Pace Analytical in Schenectady, New York, for analysis using the analytical methods listed below. These methods were in accordance with Section 3.5 of the SW&SMP and as specified in Tables 4 and 5 of the Site-Wide QAPP.

- Fish and Macroinvertebrates:
  - PCBs via Method SW 846 8082
  - Percent lipids
- Sediment samples:
  - PCBs via Method SW 846 8082
  - Grain size by Method ASTM D 422;
  - Percent solids in sediment by Method 2540; and
  - TOC via Method SM 5310 or USEPA Lloyd Kahn.

7.4 Quality Assurance

As mentioned in Section 1.5, QA/QC samples were collected during the sampling event to measure and confirm the accuracy and usability of the data in accordance with the GWMP, the SW&SMP, and the Site-Wide QAPP. Following laboratory analysis of the samples, ECCI performed data review, verification and validation to Level 2 criteria as defined in Section 5.1 and Table 7 of the Site-Wide QAPP. The Level 2 verification includes a review/evaluation of blanks, retention times, mass spectra, chromatograms, raw instrument outputs, and other information, including laboratory reporting forms, run logs, and all supporting data provided by the laboratory. The data validation reports are provided as Appendix B. No samples associated with the aquatic biota sampling were rejected or qualified by the data validation.

The DQOs for the post-closure monitoring are to provide data of sufficient quality to evaluate changes in groundwater quality over time, if any, associated with various units at the Site. As defined in Section 4.1 of the OU-07 GWMP and the SW&SMP, definitive quantitation of the concentrations of COPCs in groundwater by an off-site analytical laboratory is needed for 90% for the annual events to meet the DQO.

A total of 80 fish and six invertebrate samples were collected for analysis of eight PCBs plus lipids for a total of 774 analyses. Since none of the results were rejected, definitive quantitation for 100% of the constituents was achieved. Similarly, six sediment samples were collected for analysis of 11 constituents for a total of 66 analysis. None of the results were rejected. Therefore, definitive quantitation for 100% of the constituents was achieved.

7.5 Results

The results of the PCB and lipids analysis for the aquatic biota and sediment samples collected in September 2015 are provided in Table 23 (fish), Table 24 (macroinvertebrates), and Table 25 (sediment). The results of the grain size, TOC, and percent solids analyses are also presented on Table 25. Historical results are presented in Appendix I.

7.5.1 Fish

Table 23 presents the results of the PCBs in fish samples collected in September 2015. The findings for the PCB analyses for each fish species are summarized below. In accordance with the SW&SMP, the PCB fish tissue results were reported down to the MDL, and any positive sample result detected between the MDL and RL was reported as an estimated value (J). Both the MDL and RL are listed in Table 23.

- **Smallmouth Bass**. PCBs were detected in 13 of the 18 whole-body bass samples submitted for laboratory analysis. The total detected PCB concentrations ranged from 0.0126 J mg/kg (2015AB-BMI-1-F-BAS-O-03) to 0.0698 mg/kg (2015AB-BMI-2-F-BAS-O-03). PCBs were only detected in one filet sample (2015AB-BMI-2-F-BAS-F-03). The concentrations detected in 2015 were generally lower than those detected in past events. For example, the detected total PCB concentrations from 2013 ranged from 0.0608 to 0.387 mg/kg. Aroclor 1260 was the only Aroclor detected in any of the samples. The PCB concentrations detected in nine of the samples exceeded the VADEQ Fish Screening Value for PCBs of 0.020 mg/kg (VADEQ 2012).
    - BMI-1: Two out of the three samples exceeded the screening criterion.
    - BMI-2: All three samples exceeded the screening criterion.
    - BMI-3: None of the samples exceeded the screening criterion.
    - BMI-4: None of the samples exceeded the screening criterion.

  - BMI-5: All three samples exceeded the screening criterion.
  - BMI-6: One out of the three samples exceeded the screening criterion.

- **Redbreast Sunfish**. PCBs were detected in six of the 15 whole-body sunfish samples. The concentrations of total PCBs detected in the six samples ranged from 0.0183 J mg/kg (2015AB-BMI-2-F-SUN-02) to 0.0451 mg/kg (2015AB-BMI-1-F-SUN-02). Aroclor 1260 was the only Aroclor detected. Similar to the smallmouth bass, the detected concentrations were generally lower than those previously detected (total PCBs detected in 2013 ranged from 0.0839 to 0.213 mg/kg). Five of the six concentrations detected exceeded the screening criterion.
  - BMI-1: Both samples exceeded the screening criterion.
  - BMI-2: One out of two samples exceeded the screening criterion.
  - BMI-3: One out of three samples exceeded the screening criterion.
  - BMI-4: PCBs were not detected in any of the samples.
  - BMI-5: One out of three samples exceeded the screening criterion.
  - BMI-6: PCBs were not detected in any of the samples.

- **Northern Hogsucker and Fallfish**. PCBs were detected in eight of 13 whole-body northern hogsucker and fallfish samples. The total detected PCB concentrations ranged from 0.0157 J mg/Kg (2015AB-BMI-5-F-CRP-03) to 0.0523 mg/Kg (2015AB-BMI-2-F-CRP-02). Aroclor 1260 was the only Aroclor detected. Only one sample from this category was collected in 2013 (a single V-lip sucker was collected at BMI-5). While no PCBs were detected in that sample, the detection limit for the 2013 sampling was higher than the values detected in 2015. The PCB concentrations exceeded the screening criterion in four of the eight samples.
  - BMI-1: One of the two samples exceeded the screening criterion.
  - BMI-2: Both samples exceeded the screening criterion.
  - BMI-3: No samples were collected.
  - BMI-4: One out of the three samples exceeded the screening criterion.
  - BMI-5 & 6: None of the samples exceeded the screening criterion.

- **Comely Shiner**. PCBs were detected in 15 of the 16 whole-body comely shiner samples. The total detected PCB concentrations ranged from 0.0141 J mg/kg (2015AB-BMI-5-F-MIN-01) to 0.137 mg/kg (2015AB-BMI-4-F-MIN-01). Aroclor 1254 was detected in one sample from location BMI-2. Aroclor 1260 was the only Aroclor detected in the remaining samples. The comely shiner was collected in lieu of bluntnose minnow samples collected in 2013. The PCB concentrations in the comely shiner samples are similar to those found in the bluntnose minnow samples from 2013. The PCB concentrations exceeded the screening criterion in 11 of the 16 samples.
  - BMI-1, 2, & 3: All three samples collected at each of these locations exceeded the screening criterion.

- BMI-4: Two out of the three samples exceeded the screening criterion.
- BMI-5 & 6: None of the samples exceeded the screening criterion.

Significant decreases in PCB concentrations have been observed in the smallmouth bass and redbreast sunfish samples since 2013. Comparing the comely shiner to the previous bluntnose minnow results indicates similar concentrations between 2013 and 2015. Spatially, upstream location BMI-6 had the fewest exceedances of the screening criterion while downstream location BMI-02 had the most exceedances.

7.5.2 Benthic Macroinvertebrates (Fingernail Clams)

As indicated on Table 24, PCBs were detected in only one clam tissue sample (BMI-2). Aroclor 1260 was the only Aroclor detected. Although no PCBs were detected in these samples in 2013, the laboratory RLs and MDLs for PCBs during the 2015 event were significantly lower than those obtained in 2013. The detected PCB concentration at BMI-2 (0.0159 J mg/kg) is less than the MDL obtained in 2013. No VADEQ screening value is provided for shellfish not subject to human consumption. There are no tissue screening values for this species. Table I-3 in Appendix I shows the historical reported PCB concentrations in fingernail clam samples collected adjacent to the Site in 2012 and 2015. In addition to these two sampling events, fingernail clam samples were collected by USEPA in 1999 and the concentrations of total PCBs ranged from 0.064 to 2.81 mg/kg (USEPA 1999).

7.5.3 Sediment

Table 25 presents the results of the laboratory analysis of the sediment samples collected from the six aquatic biota monitoring stations. The table includes the results for PCBs, percent moisture, percent solids, TOC, and grain size. The results indicate the following:

- **PCB**s: PCBs were not detected in any of the six sediments samples. The laboratory RL for each individual PCB Aroclor ranged from 0.0261 to 0.0554 mg/kg (significantly lower than the RLs from 2013 of 0.0568 to 0.0705 mg/kg). However, the laboratory reported the data down to the MDL ranging from 0.0212 to 0.0263 mg/kg, and no values were detected between the MDL and RL. USEPA (1999) detected Aroclor 1260 at a concentration of 0.47 mg/kg in one of eight sediment samples at USEPA's BMI-5 location (500 feet downstream of Outfall 003) (Table A-5).
- **Percent Solids and Grain Size**: The highest percentage of solids (81.1%) was measured at location BMI-4; while the lowest percentage (37.7%) was measured at BMI-6. Samples ranged from 47.6% (BMI-1) to 97% sands (BMI-3), with most of the sands being fine and medium grained. The remaining material was a mixture of varying amounts of silt, clay, and fine gravel.
- **TOC**: The TOC concentrations ranged from 1,900 mg/kg (BMI-3 and BMI-4) to 42,000 mg/kg (BMI-6).

7.6 Conclusions

A summary of the key findings from the aquatic biota sampling event are presented below.

- Significant decreases in PCB concentrations has been observed in the smallmouth bass and redbreast sunfish samples since 2013.
- Comparing the comely shiner to the previous bluntnose minnow results indicates similar concentrations between 2013 and 2015.
- Spatially, upstream location BMI-6 had the fewest exceedances of the screening criterion while downstream location BMI-02 had the most exceedances.
- PCBs were detected in only one clam tissue sample (BMI-2) and Aroclor 1260 was the only Aroclor detected. The detected PCB concentration at BMI-2 (0.0159 J mg/kg) is less than the MDL obtained in 2013. This represents a significant decrease in concentrations since the 1999 sampling event conducted by USEPA. No VADEQ screening value is provided for shellfish not subject to human consumption.
- PCBs were not detected in the sediment samples collected from any of the six aquatic biota sample locations at concentrations above the MDL.

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FIGURES

TABLES

APPENDIX A
SAMPLING LOGS

PARSONS

APPENDIX B
DATA VALIDATION REPORTS

APPENDIX C
LABORATORY REPORTS

PARSONS

APPENDIX D
HISTORICAL GROUNDWATER RESULTS

APPENDIX E
VSWMR CONTROL CHARTS

APPENDIX F
OU-10 CONTROL CHARTS

APPENDIX G
NTCRA BASIN CONTROL CHARTS

APPENDIX H

HISTORICAL SURFACE WATER AND SEDIMENT RESULTS

PARSONS

PARSONS

APPENDIX I

HISTORICAL AQUATIC BIOTA SAMPLE RESULTS

PARSONS

PARSONS